THE DIURNAL COURSE OF EFFICIENCY

BY

HOWARD D. MARSH,

A.B., 1901, AND A.M., 1902, OHIO WESLEYAN UNIVERSITY.

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY, IN THE FACULTY OF PHILOSOPHY, COLUMBIA UNIVERSITY

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A. INTRODUCTION

RECURRENCE of phenomena is the source of all scientific knowledge. Rhythmic recurrence in nature is well known; for physics, it is perhaps the most general and fundamental characteristic, underlying the theories of the mechanics of motion, sound, heat, light and electricity. The student of astronomy finds the movements of heavenly bodies marked by like repetition. It appears in biology in a less regular way in the growth changes of vegetable and animal bodies and in a more general way in the successive generation of species; while evolution as a whole is rather completely expressed in alternation of integration and disintegration. Social life, in all its historic aspects, gives evidence of epochal development, and some sociologists have gone so far as to make repetition (as imitation, etc.) the warp of the whole social fabric.[1] Nearer the point of the present research are particular seasonal changes in individual life —yearly, quarterly, monthly, weekly, daily—of whose existence we have hints in various anthropological, physiological and pathological data, more or less closely connected with the sexual, religious and emotional life.[2]

This paper deals only with the question whether there are normally recurring variations of ability at different periods of the day. The discussion of this question is not to be found in general works on psychology, however modern, but in sundry monographs and journal articles appearing in the last fifteen years. This means that the more conservative psychologists are not yet ready to accept such recurrence as a fact. But the investigators themselves seem to consider it quite confirmed, despite the disagreements of their results when intercompared.

Part of this assurance may be due to ignorance of what others have found. The good side of this is that experimentation under such conditions has less tendency to bias, to which workers in individual psychology are perhaps more exposed than are those in other parts of the experimental field. We want not only the subjective

[1] For complete theory, see G. Tarde's *Laws of Imitation* and other social writings.

[2] Of course there is no doubt about the monthly rhythm in females. For other suggested ones, see H. Ellis, *The Psych. of Sex*, 2. 1902.

satisfaction, but also the objective recognition, of having obtained results with a definite pointing—which 'show something'. But that this should be exhibited from the negative side seems often as objectionable to the searcher as discovery of no 'general tendency'.

The writer aims to present all the important work hitherto published, having direct bearing on the problem. On account of the scope of the latter, no collection of this material at any one point is attempted, but it is introduced where most pertinent. The greatest lack in all this work lies in two things—inextensiveness of the experimental series and omission of quantitative expression of the reliability of the results.

It is easy to account for the first of these deficiencies when one remembers the nature of the problem, affecting as it does the whole duration of the day. This makes it hard indeed to secure persons to act as subjects. If the tests are short, they must be repeated on a great number of days, in which case the various conditions must be so much the longer controlled; if they are individually more extended and adequate, they demand most of the subjects' time for the days on which they are taken, and in this case accidental disturbances are more costly. Therefore the investigator is inclined to reduce either the number of days, the number of periods per day, the number of trials per period or the number of subjects tested.

This being true, the second lack mentioned is easily explained. The neglect to calculate the averages obtained—a very serious omission when differences are small and results not always harmonious—arises partly from the feeling that the material at hand is too meager to justify the calculus of probabilities. An additional difficulty is that in a series of tests day after day the curve of diurnal variation is complicated with the curve of progressive improvement due to practise. This makes it especially hard to calculate the reliability of the averages for the different hours of the day. And even the mere labor of the tests and computations is a deterrent; for it is clear that if 500 trials are thought necessary to establish a reliable measure of any function, ten times that many and ten times the calculations will be required to establish it for ten periods of the day. Other minor deterrents might be enumerated that operate in certain cases.

One other occasion for criticism of the works referred to is found in the fact that the tests for the different parts of the day have not always been made on the same day. Such procedure implies the belief that the absolute ability one exhibits on one day is the same as he would manifest at the same hour the next day or any subsequent one: it takes no account of accidental influences, practise

effects and other inherent factors of change. To keep clear of these errors, the tests for the different hours of the day should be made on the same days.

My own work is not free from the first of these criticisms, but avoids the remaining two.

In addition to presenting the work of others, the author, by a great variety of extended tests upon himself, has been able to establish definitely the course of diurnal changes for one normal subject. Six male graduate students, one female graduate, and a group of sixteen female undergraduates were likewise employed for both motor and mental tests, and the measurement of the hourly product of 22 female factory operatives contributed additional data. The tabulation of human deaths for time of day; the results of school examinations and recitation marks for different diurnal periods; the best times of day for athletic performance and for intellectual composition; in short, as wide a class of pertinent matter as could be secured has been applied to the solution of the question of diurnal changes of efficiency.

In the experimental portion of the present work, much use has been made of tests variously employed by others. The aim has been to get such variety as the practical limitations of application would allow. It is not thought that together they give a measure of 'general intelligence' or 'general motor power'. These themselves have rather a precarious existence since analytical psychology has taken an experimental turn. Our activities are recognized as much more complex than they seem, and tests of them, on the basis of simplicity, may not be productive of the most valuable knowledge. Especially is this true of adults, to whom my own tests were chiefly confined. Still it is true that legitimate and interesting results have been reached in the past and that accruing experience must make future efforts more fruitful. As the total outcome of his research, the author is not prepared to 'say the last word' about diurnal rhythms, but hopes that something worth while has been attained.

Acknowledgments are due to Professor Cattell for the original proposal of the problem and for other suggestions; to Professors Thorndike, Woodworth and Meylan, of Columbia University, for assistance of various kinds; to those who acted as subjects at much personal inconvenience; to certain officers and employees of the manufacturing firms of Dennison and Sons, J. English and Sons and the Trow Directory Company, of New York City, for courtesies extended during observational work in their respective factories; to Dr. Guilfoy, registrar of the City Health Department; and to other individuals who contributed in different ways.

B. THE COURSE OF PSYCHOPHYSIOLOGICAL EFFICIENCY

I. Vital Activities

Any strict line of demarcation between so-called physical and mental life does not exist in reality and is maintained primarily for convenience in dealing with the complex phenomena of life. For the data to be presented in this section the term psychophysiological seems best, since from the physical side only the functional aspect is dealt with. What will be called 'vital' activities are on the mental side directly concerned with emotion; 'sensory', with cognition; and 'motor,' with volition, as the words are commonly accepted. The idea is not to support a three-faculty psychology nor to stand sponsor for a rigid meaning of the terms employed. But a more systematic presentation of the subject can be given by adherence to the order named.

Considering the length of time that medicine has been studied, or even that physiology has been a separate science, one would expect to find the matter of physiological rhythms fully discussed. However, the text-books here are as barren as those in psychology with respect to the general problem. The first and only systematic collection of results was published by Vierordt in 1888[1]. The actual work was done by various medical men between 1840 and 1880, and much of it must be considered unreliable, particularly where the conditions of experimentation or observation are not stated. Only such figures as seem most trustworthy will be quoted.

1. *Secretion, Urination, Evaporation*

Vierordt's results here have no value in themselves without fuller information as to number of subjects and their habits of life, their age, sex, health, etc., together with the length and method of experimentation. The following are less deficient in these respects.

2. *Circulation, Respiration, Temperature*

1. *Circulation.*—The most commonly accepted view with regard to pulse rate is that the maximum occurs in early morning, followed by a steady decline till after midnight, broken only by the temporary

[1] *Daten und Tabellen.* 1888.

influence of meals and accidental excitements. This seems only partly true. The correctness of the first statement is greater the nearer to arising the record is taken, as will be indicated below. The following table gives most of what material could be gathered on this matter, together with some of my own.

TABLE I. PULSE RATE AND TIME OF DAY.

	7 A.M.	8	9	10	11	12	1 P.M.	2	3	4	5	6	7	8	9	10	11	12
1			* 74	71	70	69	81	84	82	77	76	75	75					
2_1		68 *					71			68			68		* 72			
2_2		73 *					83			76			68		* 69			
2_3		90 *					105			97			82		* 97			
3	68	* 81	87	73	79	67	82	83	73	73	70 *	85						
4_1		56 *					72						69 *				65	
4_2	72	* 86	83	81	76	73	79	77	75	72	78 *	84	82	77	73	70	69	68
4_3	71 *	78		74	70		77		72	70		72 *	78		76	71		
4_4	84	* 94	98		84	78	77 *	82		76		* 86				72		

1—Vierordt. Self, number of days not stated.

2—Binet. 2_1 self, 7 days; 2_2 male adult, 2 days; 2_3 female adult, 2 days.

3—Storey. Self, average of 6 to 10 determinations.

4—Marsh. 4_1 male adult, 6 days; 4_2 male adult, 15 days (summer); 4_3 same, 12 days (winter); 4_4 female adult, 7 days.

*—Indicates occurrence of meals.

Not all the series approach completeness. Small dependence can be placed on 1[1]; Binet[2] says of his own that "they are three single curves chosen from a great number because of the distinctness of the tracings", not saying that they are even representative ones; 4_1 is a short series but with small probable error.

The first four and 4_1 show the maximum rate at about 1–2 P.M. (2 also at 9 P.M.), the others at 8–9 A.M. The changes to which we are subjected on awakening act as excitants and largely cause the apparently high early morning rate. Change of position alone has great influence. Ten mornings, in my own case, the rate two minutes after arising averaged 81, as compared with 72 twenty minutes later; and again in the second series the figures were respectively 81 and 71. Subject 4_4 did the same thing a like number of days, taking an additional record in bed several minutes before arising. Her averages were 79, 87 and 84. These facts suggest what small reliance can be placed on bare pulse figures in tables. What seems to be true here, aside from the doubly induced increase due to rising and eating, is first a morning rate less high and less well sustained than the afternoon rate; second, a higher female than male rate, with

[1] Yet, as late as 1900, the *Am. Text-book of Physiol.* quotes these figures as bases for conclusions. This shows how meager is the information.

[2] 'Le Changements de Forme du Pouls Capillaire,' *L'Année Psych.*, 3. 1897.

tendency to an earlier maximum[1]; and third, a general rate higher than the 70 so long accepted as about the average.

As to the first point, the order is sustained by a recent study of blood and pulse pressures made by Erlanger and Hooker[2] with one adult subject. Five extensive tables show the results obtained for five days, at different hours from 8 A.M. till 10:30 P.M., but their reproduction here is forbidden by their great length and uncertain value. However, the authors draw this conclusion: "We therefore can distinguish a gradual increase of pulse-pressure [directly proportional to pulse-rate according to them—p. 294] throughout the day upon which is built up the wave-like increase that follows upon the ingestion of meals" (p. 343). "There seems to be no relation between the amount of food ingested and the height and duration of the post-prandial [fundamental] rise" (p. 344).

In addition to this direct evidence there are other facts in favor of the view that the pulse is normally lower in the morning than later in the day. Muscular and brain activity heighten the pulse rate on account of the increase in waste products sent to the heart. If it be true that a greater muscular power accompanies increased rate of circulation, as shown by Zablondousky[3] and Maggiora[3] with massaged muscles, and by Kronecker[3] with injection of blood into fatigued muscle, then, according to the traditional pulse theory, the greatest strength might be expected in the early morning. As a matter of fact, it is probably least then, as will be shown later.

Periodicity in pulse intensity and blood pressure, dicrotism and the rapidity of vascular reflex have been investigated, but the results are unimportant.

2. *Respiration.*—One expects to find a positive correlation between pulse rate and respiration and temperature, as they have a common dependence on the amount of metabolism in the body, the latter in turn being largely proportional to the excitement or activity at any period. And it is found to be so in fact.

Vierordt's maximum for himself was at 2 P.M. for rapidity of respiration and volume of air and of CO_2 expired, and minimum at

[1] The high night rate of 2_3 is due to the evening meal and no comparable morning figure is shown, while the case of 4_4 shows a considerable falling off towards night. Guy and Knox, per Vierordt, found a higher rate for children with an early morning maximum. Miss N. Norsworthy, of Teachers College, in a recent research, the results of which are as yet unpublished, found for girls under 15 years a rate of 95.5, and above 15, of 93—295 cases; for boys under 13, 95, and above 13, 85—253 cases.

[2] 'An Experimental Study of Blood-pressure and Pulse-pressure in Man,' *Johns Hopkins Hosp. Reps.*, **12**: 145–378. 1904.

[3] J. Joteyko, 'Revue Générale sur la Fatigue Musculaire,' *L'Année Psych.*, **5**. 1898.

7 P.M.—the last hour of his series. Binet's maximum occurred at 7–9 P.M. and minimum at 8 A.M., his series being from 8 A.M. to 8:40 P.M. Tigerstedt[1] (after Jürgensen—see Fig. 1) finds the maximum volume of CO_2 at 5–8 P.M. and minimum at 4–8 A.M.

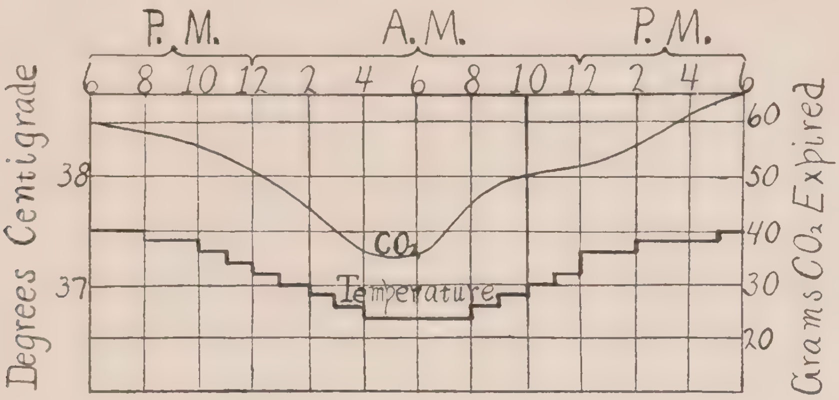


FIG. 1. Normal Variations in Body Temperature (after Tigerstedt).

Johannson[2] finds that the greatest quantity of CO_2 is given off by an active subject from 8–12 A.M. and the least from 4–6 A.M.; this was practically true also during perfect rest. His experiments were on himself, in six-hour courses of activity and, again, of inactivity (in bed), requiring different days to cover the whole twenty-four hours.

In accord with this evidence are certain data obtained from spirometric tests of Filipinos at the St. Louis Exposition,[3] where 72 were tested for lung capacity in the morning and 41 in the afternoon. The average for the morning was 170.0 cu. in., with a probable error of 1.76; and for the afternoon, 177.2, with P.E. 2.60. In my own case, eight trials at each period showed averages as follows: 7–8 A.M., 189; 9–10 A.M., 192; 11–12 A.M., 191; 1–2 P.M., 188; 3–4 P.M., 192; 5–6 P.M., 192; 7–8 P.M., 193; 9–10 P.M., 191. This follows closely the curve of my motor ability as found by many tests.

3. *Temperature.*—Reference to Table II. and Fig. 1 makes it evident that the temperature reaches the highest point about 5–8 P.M. and the lowest about 7 A.M. Johannson finds the same true for diurnal activity or rest conditions. Attention is called to the close similarity of the curves in Fig. 1, and to the close agreement of the results cited.

[1] *Lehrbuch der Physiologie.* 1902.

[2] 'Ueber die Tagesschwankungen des Stoffwechsels und der Körpertemperatur, *Skand. Archiv. für Physiol.*, **8**. 1898.

[3] Fuller reference to this work will be made later.

TABLE II. BODY TEMPERATURE AND TIME OF DAY.

	6 A.M.	7	8	9	10	11	12	1 P.M.	2	3	4	5
1_1			37.9 *					* 38.4			38.2	
1_2			37.5 *					* 37.9			37.8	
2_1		36.4	36.7 *		37.0	37.2	37.1		* 37.3			37.5
2_2		36.6	36.8 *		37.1	37.1	37.1		* 37.2			37.3
3_1	33.3	32.8	32.9	32.5	* 32.5	33.6	34.2	* 35.5	34.5	33.5	33.9	33.2
3_2	36.4	36.9	37.2	37.2	* 37.3	37.4	37.4	* 37.5	37.4	37.4	37.4	37.4
	6 P.M.	7	8	9	10	11	12	1 A.M.	2	3	4	5
1_1		38.4		* 38.5								
1_2		38.0		* 38.2								
2_1		37.4		* 37.2		36.9						
2_2		37.1		* 37.1		36.7						
3_1	34.2	35.6	36.0	35.9	35.8	35.7	35.7	35.5	35.2	34.7	35.0	35.0
3_2	37.5	37.5	37.4	37.2	37.0	37.0	36.8	36.8	36.7	36.6	36.6	36.4

1—Binet. 1_1 hand; 1_2 rectum; self, number of days not stated.

2—Vierordt. 2_1 average of Jürgensen, Liebermeister, Barensprung—rectum—days not stated; 2_2 average of Gierse, Hallmann, Lichtenfels, Frühlich—mouth—days not stated.

3—Roemer. 3_1 hand; 3_2 rectum; subjects and days not stated.

*—Indicates the occurrence of meals.

Some very interesting experiments by Galbraith and Simpson[1] on the temperature wave in the monkey may be briefly described here. The axillary temperature of six subjects was taken every two hours, day and night, under different conditions, as follows:

(*a*) Twelve days—ordinary conditions—fed at 9 A.M. and at 6 P.M.—period of activity, 9 A.M. to 9 P.M.; of rest, 9 P.M. to 9 A.M. Result: rise during activity, maximum at 5 P.M.; fall during rest, minimum at 6 A.M. This occurred *every* day.

(*b*) Six days—conditions exactly reversed (artificial light at night)—fed at 6 A.M. and at 9 P.M. Result: complete reversal of the diurnal wave in 24 hours; maximum at 2 A.M. and minimum at 5 P.M.

(*c*) Six days—active from 3 P.M. to 3 A.M., etc. Result: similar, though slower, modification of the wave; maximum at 9 P.M., minimum at noon.

(*d*) Six days—in darkness during entire time, etc. Result: wave became irregular, then gradually disappeared.

(*e*) Six days—in light whole time, etc. Result: no wave shown, but an irregular curve; animals irritable.

To verify these results, experiments on birds were next undertaken.[2] The owl reached the maximum at night and the minimum

[1] 'Conditions Influencing the Diurnal Wave in Temperature of Monkey,' *Jour. of Physiol.*, **30**, 2: 20; *Proc. Physiol. Soc.* 1903.

[2] 'Temperature Variations in Nocturnal and Other Birds,' *op. cit.*

in daytime. The thrush, on the other hand, reached these points at noon and midnight, the difference amounting to over 5 degrees centigrade. Gulls, pigeons and three varieties of ducks showed similar variations; the smaller the bird the greater was the diurnal variation.

The recurrent rhythm of day and night and the consequent habitual alternation of activity and rest are seen to be the all-important factors here, as they are also, probably, for men. Unfortunately, no analogous human experiments have yet been made.

3. *Deaths Relative to Time of Day*

Kirkpatrick,[1] discussing fatigue, makes the remark (p. 327) that since more deaths occur about 4 A.M. than any other hour, vitality is then probably lowest. He cites no authority for this statement, nor has the writer been able to locate any in print, though it appears to be widely accepted as a fact, even by physicians who have been personally questioned. To determine the facts 36,000 records of

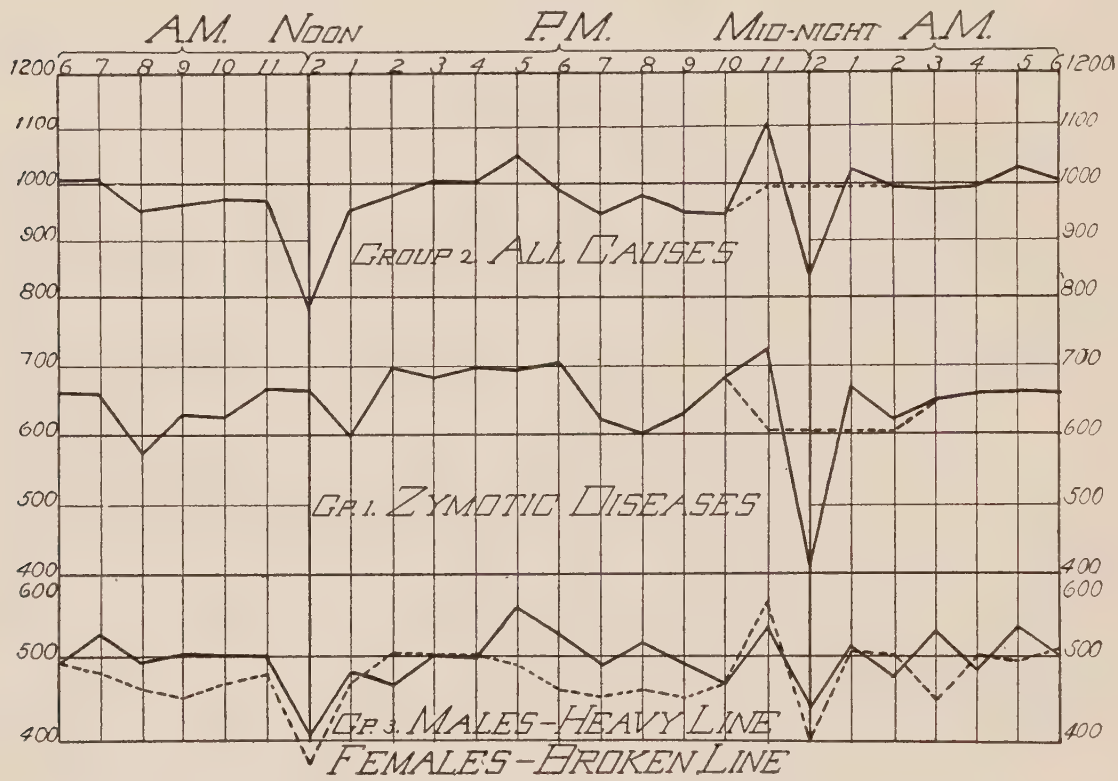
TABLE III. DEATHS RELATIVE TO TIME OF DAY.

Description of Group.	Total No.	6 A.M.	7	8	9	10	11	12	1 P.M.	2	3	4	5
Zymotic cases....	15,616	660	659	579	631	628	668	665	598	695	687	697	693
All causes.........	23,439	1003	1007	953	959	970	981	782	955	980	1009	1006	1054
Males............	11,991	493	525	491	506	501	501	409	484	471	505	500	562
Females.........	11,448	510	482	462	453	469	480	373	471	509	504	501	492
Age—M. & F.													
1- 5............		227	211	209	171	178	195	152	176	202	203	180	203
6-25............		113	137	115	130	122	125	96	117	123	105	122	119
26-45............		268	272	245	261	272	264	229	268	275	296	286	273
46-65............		241	229	237	248	238	242	185	239	239	253	247	276
66-95............		154	158	147	149	160	155	120	155	141	152	166	183
Season, M. & F.													
Nov.-Feb.		369	359	348	360	380	330	270	324	312	371	372	361
Mar.-June......		358	381	373	339	325	372	269	336	375	357	351	378
July-Oct.......		276	267	232	260	265	279	243	295	293	281	278	315

Description of Group.	Total No.	6 P.M.	7	8	9	10	11	12	1 A.M.	2	3	4	5
Zymotic cases....		709	623	603	634	688	723	412	669	624	651	660	663
All causes.........		994	948	984	947	942	1107	847	1026	994	981	986	1029
Males............		530	493	520	492	471	540	441	514	490	532	485	535
Females.........		464	455	464	455	471	567	406	512	504	449	501	494
Age—M. & F.													
1- 5............		201	181	181	200	162	219	138	200	211	190	190	212
6-25............		119	94	135	127	127	135	98	122	130	107	114	130
26-45............		256	275	267	263	263	281	248	285	250	301	268	282
46-65............		272	245	249	208	238	300	201	286	258	245	244	253
66-95............		146	153	152	149	152	172	162	133	145	137	172	152
Season, M. & F.													
Nov.-Feb.......		325	324	375	336	327	434	323	410	379	348	361	383
Mar.-June......		354	351	319	333	331	377	276	318	332	332	359	369
July-Oct.......		315	273	290	278	284	296	248	298	283	301	266	277

[1] *Fundamentals of Child Study.* 1903.

deaths occurring in New York City in 1901 were worked over by the writer. Those cases were excluded in which death was caused by suicide or accident, those of children under one year in age, and those where the hour was omitted from the doctor's certificate. Males and females were recorded separately and in the following age groups: 1–5, 6–25, 26–45, 46–65, 66–95. Three seasons of the year were also noted: November–February inclusive, March–June, July–October. For each of the months 3,000 cases were used, but after making the above exclusions only 23,439 remained. In addition to these, Table III. reports 15,516 deaths from zymotic diseases, which had been tabulated for each hour of the day in the official records of the city Health Department for the years 1876–79. No others were found for subsequent years, up to date. In all but the first group 6 A.M. means from 5:30 to 6:30; what it means in the first group was not discovered.



Figures at the sides indicate number of cases.

FIG. 2. Deaths Relative to Time of Day—see Table III.

This table and these curves of the chief groups are by no means easy of interpretation as they stand. This is mainly due to one peculiarity, affecting every group, which must first of all be accounted for if possible. This is the notably apparent decrease in deaths at the noon and midnight periods. Its occurrence at these particular points is *prima facie* evidence that a real fact is not disclosed, and its occurrence in all groups is convincing proof of some external cause. It can probably be explained if Kant's philosophic theorizing be allowed—that 'man is by nature lazy'. This seems a

far cry to the present matter, but a few words will make it plain. The attending physician must certify, as to the hour of a patient's death, that so-and-so died 'at — M.' This works happily enough till the periods in question are involved, when immediately arises the necessity of writing out in full the words 'noon' and 'midnight' for the sake of their clear distinction.[1] Rather than take this trouble, the indifferent doctor will do one of two things—either leave the space blank or make the record for the closely preceding or succeeding hours. In the first event a like loss is occasioned in the two periods, since the record does not then differ from those left blank for other reasons, all of which records had to be excluded. The cases thus affected would account for only a small part of the apparent decrease—possibly one tenth. In the other event, the adjacent periods should show decided increase. That is precisely what they do at midnight, sufficiently to smooth the curves from 10 P.M. till 2 A.M. inclusive, as indicated by the dotted lines in Fig. 2. It is not so evident at noon, and there may be a real decrease at that hour —a possibility somewhat emphasized by the 1 o'clock drop in the first group.

The first two curves are similar throughout, save at noon. When corrected as suggested they are easier to compare. The highest rate in each occurs, not at 4 A.M., but from 2 to 6 P.M.; and the minimum, less well marked, immediately after—from 7 to 12 P.M. An examination of the figures of the sex group shows much the same order, the females reaching a slightly earlier maximum than the males, while 3 A.M. and 5 P.M. are the only points of notable opposition. The female rate is more regular than the male. In the age group, 26–45 most resembles the female curve and 46–65 the male. In the season group, the July–October curve most nearly follows that for all deaths.

Just what these results mean is puzzling. The differences are frequently much above those easily accounted for by chance. While the number of cases seems large, it is only about one fourth large enough. The sub-groups for age and times of year are far from

[1] This would not be the case if many people, including doctors, did not think that M stands for midnight as well as for meridian, while some think it stands for nothing else. The first set of figures is seen, relative to the second, to show a much less noon and a much greater midnight drop. This is best accounted for by supposing that the compiler included at the former period all cases marked '12 M.,' whereas part doubtless belonged to the latter period. The same is less true of the second set because some of these cases were distributed to the later period. Attention is called to the fact that these points are disregarded in the 'smoothings' shown in Fig. 2, but should be remembered in connection with the further discussion of the curves.

being extensive enough to throw adequate light on the causal factors involved. Even after combining the male and female figures, each period of these groups is poorly represented; but such a combination is scarcely allowable. Confining attention to the first three groups, the venture of a definite opinion might be hazarded.

At first thought one would be tempted to infer from the occurrence of the maximum at the warmest part of the day, that the heat was the important factor. But inspection of the seasonal figures shows a much lower death rate in July–October than in winter, while the curve for the summer months closely resembles the general curve. Heat alone offers no solution.

The following theory is more in harmony with the facts: the vast majority of these people died of disease and not of old age. The proportion of sudden to gradual deaths was, on the whole, small. The 'average patient' (to generalize for adults) on awakening is fed, and for an hour his death rate is lowered, food influence being often eked out by a nap. His waking troubles begin thereafter and cause a rise in the rate till at noon he is again fed and reduced to a minimum of activity for an hour or two. Then the troubles and frettings are resumed more vigorously, the body having now become thoroughly 'warmed up', and the actions responsive to this increased state of stimulation sap the energy more rapidly, till the final surrender takes place about 5 or 6 P.M. For the survivors, there is at this time another meal and consequent lowering of the curve, which is again emphasized by longer sleep, during which there is a gradual, slight rise in rate till the morning awakening.

This idea is supported by the time of occurrence of the highest and lowest rates in the age groups. A close scrutiny, with the suggested smoothing always in mind, reveals that the maximum for ages 1–5 is very early in the morning—before 9; that for 6–25, from 7 to 11 A.M.; that for 26–45, about 3 to 4 P.M.; and for the following years, about 5 to 6 P.M. The curve of diurnal activity probably varies rather similarly with age. A large increase in the number of cases would be of marked value, as it is evident that these groups are not only too wide, but are also rendered too heterogeneous by the sex element. The minimum locations are likewise confirmatory, as they uniformly occur at the customary points of least activity—meal-times and night.

At all events, the 4 A.M. idea is effectively exploded. The cases are numerous enough to establish this point reliably. The females of the second group show a drop at 3 A.M., which is offset by a male rise and hence a straight line appears in the curve of the whole group for this part of the night. As a matter of fact, the time from

1 to 5 A.M. is but a trifle higher in death rate than the median for the whole day. The body temperature and expiration of CO_2, as shown by Fig. 1, would lead one offhand to expect the greatest number of deaths about 4 or 5 A.M. The fact that they do not come at this point of apparently lowest vitality, throws us back to the conclusion already drawn. It appears paradoxical to call the point of greatest strength—a fact to be later demonstrated—the most likely death point, yet it is really not unreasonable. It is well known that patients usually grow worse towards evening. The successive moments of pain or chafing throughout the day act in a cumulative way physiopsychologically, causing increased irritation, which excites to the expenditure of more energy than the system can afford to lose.

4. *Brief Summary*

It may be said that, in a general way and ignoring the immediate effects of meals as far as possible, the heart and lung functions and body temperature tend to vary alike, beginning with a very early minimum—about 5 A.M.—and increasing to a late afternoon maximum—about 5 P.M. There is ground for believing that women reach an earlier maximum than men, at a higher rate, and children a still earlier maximum at a still higher rate. Similar facts seem to hold good in the case of animals, where it is found that the periods of rest and activity determine the curve entirely. While the same maximal period holds for human deaths, the minimal one is from 7 to 11 P.M., females again coming to an earlier maximum than males, and young children to a very early one. Contrary to what one would anticipate, the maximal death rate in each of these groups falls very near to the time where we are led in normal life to look for the greatest physical efficiency, as evidenced by muscular power. This is most likely due to the fact that, in the main, at these periods the most effective stimuli are in operation, externally and internally, and cause an over-expenditure of energy from which it is impossible for many patients to rally. While a sort of physical weakness probably exists very early in the morning, it is not true, as held by popular opinion, that we are 'nearest death' at that particular portion of the day.

II. Sensory Activities

1. *Sight, Color-sense and Hearing*

In some psychological experiments on various peoples at the St. Louis World's Fair, in which the author assisted those in charge of this section of the exposition—Dr. R. S. Woodworth and Mr. F.

G. Bruner, of Columbia University—the sight and hearing of over 100 Filipinos were tested between 9:30 A.M. and 12 M., or between 2 P.M. and 4:30 P.M. For acuity of vision the so-called E-test was used, in which lines of E's of successively smaller sizes and pointing in different directions are arranged on a chart like the ordinary letter charts for optical tests, and the greatest distance, at which the subject can recognize the positions of the E's in each line, is determined. The results give the average ratio of the distances so determined to the standard distances. There were 70 cases in the morning, giving an average of 1.90, and 38 in the afternoon, averaging 1.94. That is, the difference is little better than one of chance.

The same subjects, in matching a series of shades of colors with a series of tints, averaged respectively 11.8 and 11.5 errors, thus favoring the morning, but only to the chance degree.

In acuity of hearing, as tested by apparatus devised by Mr. Bruner for the purpose, 37 men in the morning showed an average ability slightly inferior to that of 23 men in the afternoon. The numbers are too small to make this difference significant.

2. *Skin-sensitivity and Pressure-sense*

What work there is here bearing on diurnal variation is best discussed under the headings of attention (p. 43 and Table XIV.) and fatigue (p. 79 and Tables XXX., XXXI. and XXXII.).

3. *Brief Summary*

No diurnal changes in sensory efficiency are suggested by the scanty data at hand, save a possible low skin-sensitivity in early morning.

III. MOTOR ACTIVITIES

1. *Subhuman Data*

1. *Plant Life.*—The following statements are of some interest for comparison with human data. Sachs says, "If a plant, which has been exposed to the alternations of day and night, be kept in darkness for a considerable time, the periodicity (due to light) may continue for a time, according to Pfeffer, as a *persistent* effect."[1] Pierce bases the following statements on work by Sachs: "The daily periodicity of light and darkness is almost coincident with the daily periodicity in growth rates. . . . The rate of growth in length, of plants furnished with all the food they need, will reach its maximum about sunrise and its minimum about sunset."[2]

[1] *American Text-book of Botany*, p. 883. 1882.
[2] *Plant Physiology*, p. 211. 1903.

2. *Animal Life.*—Hodge and Aikins,[1] experimenting with one of the Protozoa, found the ciliary activity of this animal, by which food is injected and detritus ejected, to be apparently without periods of rest corresponding to those of higher animals. This constancy seems unaffected by reproduction, barometric pressure, light, heat, or sound. In their diagram of the activities of the animal, the most pronounced vesicular and stalk contractions and reproductive phases appear to be recurrent in the early morning. These are of the same order as man's motor and reproductive activities, while the unintermittent character of the ciliary activity is what might be anticipated when it is remembered that this undifferentiated functioning in these unicellular animals is that which, in developed form, finds expression in our unremitting circulatory and respiratory performances. With advance up the animal scale the number of rhythmic activities slowly increases.

2. *Human Data*

1. *General Characteristics of the Writer's Methods and Experiments.*—To determine with scientific exactness the diurnal course of any activity would require a minute consideration of the subject's daily physical and mental condition, the character of his daily work and habits—as to regularity and irregularity, quantity and quality—and of all external and accidental influences to which he might be subjected at any period of the day. It would be impossible to ascertain accurately all these matters, but practically what we want to know is what one does accomplish under just such heterogeneous circumstances—the ordinary conditions of life. Allowances were made for several serious interruptions, and where illness occurred the records were not used.

In order to insure the greatest variety of material, the data were gathered not merely from strictly laboratory tests, but also from those less capable of exact measurement in standard terms; and, in addition, the questionnaire method was attempted and data from general and school work utilized. The tests were applied extensively to groups of subjects for one or two days, and intensively to individual subjects for several weeks. Some information as to the subjects, periods and tests used and as to results and their statistical treatment must be given.

Subjects. The males were seven in number, all graduate students at Columbia University, ranging in age from 26 to 34, and will be referred to hereafter as I., II.–VII. All were conversant with and practised in laboratory work; hence each acted as both operator and

[1] 'Daily Life of a Protozoan,' *Am. Jour. of Psych.*, **6**: 524–533. 1895.

subject in his own case, after full verbal and written instructions on every test of his series. The letter 'A' will be used to represent a female graduate student, 23 years old, engaged in intellectual work 10 to 13 hours daily; 'B' is a group of young women of Teachers College, ranging in age from 20 to 35. Both A and B were naïve subjects, and their tests were given by myself.

Periods. The tests were to be taken daily before breakfast, lunch, dinner and bedtime. The actual times at which they were taken necessarily varied somewhat for different persons, this being one of the great practical difficulties of the problem. To get reliable results one must start with reliable subjects, but they are just the ones who can least afford to distort their affairs daily for so long a time. The periods in the tables are two hours broad to allow classification of the subjects together.

Tests. Each subject went through the tests for about twelve days; the exact numbers will be indicated in the following pages, to which reference must also be made for detailed descriptions of the various tests. About six sorts of tests, motor and mental, were given to each subject, except that subject I. (the author) took a much greater number. But the results of some of the tests admit of double measurement—for speed and for accuracy—and appear so in the tables. The 'number' given in the second column of some tables has reference to the trials at each period and not to the total number in the whole series.

Results and Statistical Treatment. The results are from whole days' records, as already suggested.[1] All results are in terms of the average and its probable error, the formula used for calculating the latter being $\pm 0.6745(\sigma/\sqrt{n})$, where σ is the mean square deviation and n the number of cases. The mathematical chances are even that the average shown will not vary from the real (theoretical) average by more than the limits of the P.E. It should perhaps be remarked that it was necessary, though less desirable, to have the higher figures represent greater degrees of inefficiency instead of efficiency; the larger the numbers, therefore, the less the efficiency. Corrections were frequently made for practise effect. There would be no occasion for this if only averages were sought, but it is absolutely required when a figure for their reliability is wanted. The method used for eliminating the practise effect was to make an empirically graduated scale of allowance for the successive days, which was based, as to the whole amount, on the absolute differences between the initial and final records and which took advantage, as to graduation,

[1] See p. 3.

of the established fact that the effect of practise is at first very pronounced and then decreases more slowly. There are two assumptions in the method: first, that practise affects all the periods of the day equally; second, that any possible correction thus made and applied to all the periods alike is legitimate, however low it reduces the probable errors, since these will always remain higher than if a perfectly adjusted and full correction could be made. The first assumption may or may not be true, but it seems to me that no exception can be taken to the second. Any correction of a constant error is almost sure to be nearer the truth than any uncorrected figure, as it is then transferred to the rank of chance where elimination of its influence by others is much more likely to occur. When a 'total' average in the tables refers to only a few individuals, it should not withdraw attention from the separate records themselves, where the main truth is then most probably located.

What has been said above refers also to the mental tests, which were taken by each subject at the same times as the motor ones. The mass of details to be handled makes the briefest treatment necessary at every point, with elimination of repetitions as far as possible.

2. *Actual Tests and Results—writer's and others'. a. Speed and Accuracy of Movement.*—As a rather simple form of movement the subjects were required each period to strike with a pencil point, as rapidly as possible, 200 small squares (1 cm.) arranged in 10 columns of 20 each. The time of performance gives the measure of speed, while the number of squares missed roughly indicates the (in)accuracy. None of the subjects except the writer knew that the accuracy was to be considered. Table IV. shows the results and, for convenience of comparison, those of a test treated in the immediately following sub-section.

A small correction was made for practise. The greatest deficiency appears at morning and night periods, a difference that is significant,[1] as seen by the P.E.'s of each average and the uniformity of the individual results. But the inaccuracy maximum and minimum seem just the reverse, and this may account for the preceding differences entirely or in part.

The group of young women, B, in taking this test, were allowed 45 seconds to strike 200 squares or as many of them as possible. The results show somewhat the same inverse relation of speed and accuracy and the same order of rate efficiency as the individual cases. The improvement here might, however, be attributed to practise.

[1] The exact significance of a difference can be found by various formulæ: see Thorndike's *Mental and Social Measurements*, p. 145. But it can be seen well enough, often, by inspection of the P.E.'s.

TABLE. IV. SPEED AND ACCURACY OF MOVEMENT—SQUARES AND WORDS.

Subject.	No. Squares.	7–9 A.M.				12–2 P.M.				4–6 P.M.				9–11 P.M.			
		Time.	P. E.	Misses.	P. E.	Time.	P. E.	Misses.	P. E.	Time.	P. E.	Misses.	P. E.	Time.	P. E.	Misses.	P. E.
I.	2800	38.3	0.87	6.1	1.40	32.4	0.52	10.6	1.53	32.8	0.57	6.9	1.45	35.1	0.71	5.2	0.68
II.	2400	46.3	0.86	6.7	1.12	44.4	0.55	5.0	0.97	46.1	0.47	5.1	0.81	48.7	0.87	4.3	0.70
IV.	2000	58.6	0.51	5.2	0.84	56.2	0.32	5.6	0.94	55.6	0.63	5.7	0.78	57.4	0.54	5.7	0.66
Average	2400	47.7	0.75	6.0	1.12	44.3	0.46	7.1	1.15	44.8	0.56	5.6	1.01	47.1	0.71	5.1	0.68
A	1400	60.6	0.63	4.6	0.25					59.0	0.45	4.1	0.25	61.0	0.41	3.6	0.31
	Words.																
I.	600	86	0.5			80	0.6			81	0.4			84	0.3		
IV.	600	88	0.6			84	0.6			85	0.6			86	0.5		
V.	576	70	0.4			66	0.5			69	0.6			71	0.4		
Average		81	0.5			*77*	*0.6*			78	0.5			80	0.4		
A	350	92	0.5							92	0.8			93	0.8		
	Squares Undone																
B	3200	54	4.1	4.8	1.9	50	3.2	3.8	1.7	46	4.0	5.2	1.9				
	Words Done																
B		60	1.0			61	1.5			62	1.2						

Another sort of accuracy test in my own case gave about the same result. The so-called hold-and-let-go method was employed in a twelve-day series in which a light (4 gr.) wooden disk was snapped, on a smooth board, toward an aperture slightly larger, 60 cm. distant. This was done ten times per period each day and the inaccuracy measured by the average distance at which the disk lodged from the hole. These averages for the four periods, which have large P.E.'s, were obtained.

Right	9.3	8.3	7.6	8.7
Left	12.1	11.4	11.4	12.5

The middle periods of the day still remain better than the morning and evening.

A more complex movement was tested by having several subjects write the numeral words 'one' to 'twelve' five times each period and the time taken. Group B wrote as many words as possible in 90 seconds. The results, in the above table, rather confirm the order of deficiency in speed, as found for the simpler movements.

At the Department of Psychometry and Anthropometry of the St. Louis World's Fair many people were subjected to various tests, as above mentioned, and their records were kindly put at my disposal. Only a part of them could be used for the problem of periodicity. Two movement tests were used which need some description (see right end of Table V.).

The 'accuracy' test was devised by Dr. Woodworth and consisted of an equilateral triangular piece of hard wood into each apex of which was inserted a brass circular plate containing a central hole 6 mm. in diameter and 25 mm. deep. These holes were 12 cm. apart and an electrical arrangement was made whereby a bell was rung every time a metal 'poker', a trifle less in diameter than the holes, was pushed to the bottom of any one of them. The method was to hit the holes as rapidly as possible in succession, count being kept by the operator of the record made per minute. The accuracy was therefore measured in terms of the rate at which the accurate movement could be repeated.

The apparatus for measuring the 'rate of tapping' was also of an electrical nature. A brass plate, about 10 cm. across, was connected with a mechanical counter[1]; the circuit was closed and the counter moved forward one point every time contact was made, by tapping, between the plate and a short copper rod, held by the subject. The time for 100 taps was taken by a stop-watch.

[1] Kindly supplied by the C. H. Stoelting Co., Chicago, Ill.

TABLE V. ST. LOUIS EXPOSITION PSYCHOLOGICAL LABORATORY DATA—MOTOR FUNCTIONS.

Subjects: Description of Groups.	Sex.	Number.	Periods of Day.	Back Kilos.	Legs Kilos.	Forearm Strength. Right.	Forearm Strength. Left.	Accuracy—No. per Minute. Right.	Accuracy—No. per Minute. Left.	Tapping—Time per 100. Right.	Tapping—Time per 100. Left.
Filipinos—Band men	Male (1)	38	A.M.	121.8	179.2	46.4	41.8	*100.4*	90.3	13.9	15.6
		40	P.M.	131.1	199.5	46.5	42.5	100.1	90.7	13.2	14.6
" Scouts and Constabulary	" (2)	72	"	133.0	231.4	50.3	45.3	94.3	85.1	14.4	16.4
		196	"	142.2	235.4	50.8	46.0	99.5	91.1	13.9	15.6
Whites—Age, 20–50 years	" (3)	19	"			55.1	50.3	*90.6*	*84.1*	13.7	16.5
		11	"			56.0	51.1	90.2	79.3	13.3	16.3
" " " "	" (4)	31	9–11			59.8	*55.6*	103.8	93.9	14.0	16.2
		41	11–1			60.4	55.5	106.4	90.4	*13.6*	*15.9*
		47	1–3			60.8	54.3	106.7	96.5	13.7	15.9
		60	3–5 "			60.7	54.4	105.6	93.2	13.8	16.0
" " " "	" (5)	89	9–11			56.0	50.4			14.3	*16.3*
		79	11–1			58.5	*53.6*			14.1	16.3
		12	1–3			56.1	50.9			14.1	16.4
		66	3–5			58.7	53.1			14.4	16.6
		30	5–7			56.5	52.0			14.5	16.5
Number of groups with greater, and less, A. M. than P. M. efficiency.				> 0; < 5.		> 2; < 8.		> 3; < 5.		> 3; < 5.	
Whites—Age, 20–50 years	Female (1)	42	A.M.			36.6	*35.7*	106.4	92.9	14.2	15.7
		22	P.M.			37.3	34.1	109.0	93.9	14.0	15.5
" " " "	" (2)	11	"			*39.9*	*33.5*	*86.4*	75.2	*14.2*	*16.3*
		19	"			38.2	32.7	86.3	76.3	14.4	16.3
" " " "	" (3)	14	9–11			36.4	31.5			14.9	16.7
		64	11–1			36.7	32.7			15.0	17.1
		4	1–3			37.1	33.8			14.6	15.5
		24	3–5			35.0	31.6			14.4	16.2
		7	5–7			35.1	32.4			14.3	16.5
Number of groups with greater, and less, A. M. than P. M. efficiency.						> 3; < 3.		> 1; < 3.		> 2; < 4.	

In the strength and accuracy records, contrary to the usual rule in the tables, the larger numbers indicate the greater efficiency. The few cases in which the morning divisions surpassed the afternoon are indicated in the table by italicized figures, and the number of such cases as compared with those in which the afternoon sections are the better, is indicated at the bottom of each column.

A glance at the table of results reveals five groups of males and three of females, a separation made necessary by the special conditions obtaining in each. The Filipino 'band-men' are separated from the 'scouts' and 'constabulary' because, being musicians, they were a highly selected group, and in fact, as the results show, they were much quicker and more accurate, but much less strong, than the ordinary soldiers composing the other groups.[1] The first group of white males and females comprises individuals taken through a long series of tests and measurements, and their records will be found much lower than those of the succeeding groups, which were taken under highly competitive conditions and only in the activities shown. (4), of the males, and (2), of the females, as well as many of the Filipino records were taken by myself.

Since the morning and afternoon divisions of these groups were composed of different persons, the practise effect, so troublesome in most of my other series, is avoided here. But offsetting that advantage is the great difference between individuals, which raises the variability of each group and diminishes the reliability of the averages. The P.E.'s are indeed so large that it did not seem worth while to insert them in the table. While no special significance can be assigned to the difference between the morning and afternoon results of any single group, the general tendency of the whole table seems plain. The number of groups in which the afternoon records surpass the morning is greater than can reasonably be assigned to chance. This tendency to increased motor efficiency in the afternoon is slightly less marked in the female groups than in the male. As a whole, therefore, these results lean the same way as those in the more intensive series.

Use of the same apparatus by myself gave the results exhibited in Table VI. There were two series of tapping tests. The first was for twelve days, in each of which the time was taken for 200 taps at ten different periods. In a later one for five days, the time of 200 taps was taken six times at each of seven periods, every 200 alternating with an accuracy test of the time required to ring the bell 100 times.

The thing most worthy of note in this table, aside from the general agreement with the tendencies found above, is the exceptional occurrence and decisiveness of the maximum tapping rate at 9–10 P.M.—less distinctly manifested in the case of the right hand than of the left. The maximum of accuracy clearly comes earlier in the

[1] Of the soldiers, all those shorter than five feet or taller than five feet six inches are excluded, because it so happened that a larger proportion of short men were tested in the morning and of tall men in the afternoon.

TABLE VI. RATE OF TAPPING (TIME PER 200) AND ACCURACY OF MOVEMENT (TIME PER 100)—IN TENTHS OF A SECOND.

Subject I.	Hand Used.	No. of Trials.	7:00 A.M. Time. P.E.	8:30 A.M. Time. P.E.	10:00 A.M. Time. P.E.	11:30 A.M. Time. P.E.	1:30 P.M. Time. P.E.	3:00 P.M. Time. P.E.	4:30 P.M. Time. P.E.	6:00 P.M. Time. P.E.	7:30 P.M. Time. P.E.	9:00 P.M. Time. P.E.	10:30 P.M. Time. P.E.
Tapping	Right	12	207 *0.64*	205 *0.70*	204 *0.62*	205 *0.65*	204 *0.72*	204 *0.55*	208 *0.78*	207 *0.72*	206 *0.59*	205 *0.78*	206 *0.57*
	Right	30	201 *1.19*	200 *1.19*					202 *1.11*	203 *1.22*	202 *0.84*	197 *0.93*	198 *1.08*
Average		21	**204** *0.91*	**202** *0.94*					**205** *0.94*	**205** *0.97*	**204** *0.71*	**201** *0.85*	**202** *0.82*
Tapping	Left	12	189 *0.89*	186 *0.85*	184 *0.85*	185 *0.61*	182 *0.92*	182 *0.80*	185 *1.51*	184 *0.71*	182 *1.68*	179 *0.98*	181 *0.72*
	Left	30	179 *0.86*	174 *0.72*					176 *0.62*	179 *0.45*	175 *0.59*	173 *0.41*	174 *0.48*
Average		21	**184** *0.87*	**180** *0.78*					**180** *1.06*	**181** *0.58*	**178** *1.13*	**176** *0.69*	**177** *0.60*
Accuracy	Right	30	458 3.66	454 3.33					438 3.17	446 3.66	451 3.46	443 2.77	449 2.97
	Left	30	521 2.64	524 2.68					497 2.57	508 3.05	509 2.21	515 2.74	526 2.65

The time taken for 200 taps, and for 100 accurate movements, is given in tenths of a second. Slight practise effect was found when only 200 taps at a period was the rule, but much more proportionately in the second series when 1,200 were taken, although it came after the other. The increase for the left hand was much more regular than for the right. Correction for practise was made mainly in the second series. The seeming eccentricities of the P.E.'s are thus fully explained.

day than the maximum of speed; a shorter series of accuracy tests, with the same subject, tended to place the maximum earlier than 4:30 P.M.; there is no doubt that it falls somewhere in the middle portion of the day.

It is obvious that the rating in accuracy, secured by use of this test, has some dependence on the rapidity of the movements involved. To see if any change of order would be effected, if the factor of speed were eliminated, the following trial was made. 100 dots, 1 cm. apart, were arranged in ten (printed) rows, both vertical and horizontal. By a free-hand, easy and uniform movement, with a fountain pen, these rows were successively traced over both horizontally and vertically, 100 in each direction being done at a period. The results are in terms of the average number of dots missed every ten lines.

TABLE VII.

	No. of	7:30 A.M.		9:30		11:30		1:30 P.M.		3:30		5:30		7:30		9:30		11:30	
	Rows.	Misses.	P.E.	Mis.	P.E.	Mis.	P.E.	Mis.	P.E.	Mis.	P.E.	Mis.	P.E.	Mis.	P.E.	Mis.	P.E.	Mis.	P.E.
1.	100	0.85	*.23*	0.80	*.19*	0.82	*.19*	1.11	*.15*	0.98	*.22*	1.10	*.22*	1.21	*.33*	1.24	*.23*	1.33	*.31*
2.	100	2.10	*.41*	1.71	*.34*	1.92	*.48*	2.82	*.54*	1.83	*.35*	1.99	*.24*	2.72	*.36*	3.03	*.50*	2.94	*.52*

1. Horizontal rows. 2. Vertical rows.

This test served to confirm the other to a considerable degree, doubtless due to the chief common elements—motor control and keenness, with quickness of sight. The main divergence is at the second period, which the results make the best of the day. It is seen that the diurnal curve is the same for both horizontal and vertical rows, and this helps to confirm periodic differences which the large P.E.'s made doubtful, though these are mainly due to uncorrected practise effect and shortness of the series. The curve of these figures, if plotted, closely resembles that of the writer's diurnal efficiency as subjectively estimated.

The diurnal course of speed of tapping seems from these results to differ markedly from the course of accuracy of movement. Both are alike in showing a low state of efficiency in the first hours after rising, but after that their curves are nearly inverse to each other. Pure accuracy appears to reach a maximum in the later morning hours, while tapping, in my own case at least, is at its best in the evening, when accuracy is about at its worst. Tapping also gives a different diurnal curve from other tests of speed, such as striking squares or writing numerals. In explanation of this difference, it is suggested that rapidity of tapping, as it requires a minimum of control but a maximum of neural excitement, may be expressive largely of 'nervousness.' If a person is most nervous in the evening —and this agrees with my own introspection—he would accordingly

be quickest in tapping at that time, but not most accurate in motor control.

b. Normal Muscular Power. (*a*) *Small and Large Muscular Groups.* Since many of the conclusions as to muscular power and fatigue are based on work with small sets of muscles, it is a question of importance whether their efficiency at any time is a trustworthy symptom of the general muscular power. This will be discussed incidentally.

First, the Cattell 1903 type of spring ergometer was used by subject I. to register 50 contractions of the thumb and forefinger of each hand, at every period, for 15 days; subject A made 40 contractions at each period for 14 days. However, the first 4 days, in both cases, were omitted for practise. The figures in the table show the average number of kilos for 25 and 40 contractions, for the respective subjects, and the P.E.'s.

TABLE VIII.

Subject.	No. of Contractions.	8–9 A.M.				3:30 to 4:30 P.M.				10:30 to 11:30 P.M.			
		Right.	P.E.	Left.	P.E.	Right.	P.E.	Left.	P.E.	Right.	P.E.	Left.	P.E.
I. 1st 25..	300	143	1.0	115	0.8	149	1.0	115	0.6	142	0.9	109	0.8
2d 25...	300	107	0.9	92	0.9	111	0.8	96	0.7	109	1.1	88	0.9
Average...	300	125	1.0	103	0.9	130	0.9	105	0.7	125	1.0	98	0.9
A—@ 40..	400	126	1.9	115	2.2	137	1.7	125	1.9	124	2.3	119	2.2

With subject I. the record was kept for each half of the 50 contractions. The table shows some fluctuations, but on the whole both subjects show most strength in the middle period, as will be found to be generally true for strength.[1]

Lombard,[2] working with the Mosso ergograph as modified by himself, found the maximum power of the flexor muscles of the second finger to be reached at 10 A.M. and 10 P.M. (the higher maximum) daily, and the minimum at 4 A.M. and 4 P.M. (the lower minimum). He assigns the diurnal rhythm of atmospheric pressure as the cause of these changes in motor power. In the same article it is

[1] A cruder form of test was used by I., involving the hold-and-let-go method already mentioned. A lead ball, weighing 90 cm., was snapped, or 'plumped' marble fashion, as far as possible on a soft board, marked off in centimeters. It registered its own distance each time by spots, which were erased after every 10 snaps (the number taken with *both* hands at 7 A.M., 12 M., 5 and 10 P.M, for 12 days). The results, in average cm. distances, were as follows: for the right hand, 54, 56, 57, 54; and for the left, 50, 55, 56, 53. Only the greatest-least differences here are of consequence, though the order seems without doubt a real one with me.

[2] 'Some Influences Affecting the Power of Voluntary Muscular Contractions,' *Jour. of Physiol.*, **13.** 1892.

found that, among various influences increasing the power, food and sleep are very important. With this true his morning maximum should be much in excess of the night one, but, as a matter of fact, it is less. It is also hard to see how the slight barometric change occurring at Worcester, where the experiments were made, could be so decidedly influential. Lombard[1] also found the diurnal variations in height of knee-jerk to be directly related to the barometric pressure and inversely to the temperature, but mainly dependent on hunger and fatigue, which are highly depressive (p. 67). Here the order was a morning maximum and a minimum at night, the decline being irregular; in general the knee-jerk was larger after each meal (p. 68).

Patrizi,[2] using the Mosso machine in experiments on himself and another adult male in early morning, early afternoon, evening and midnight, discovered the 2:30 P.M. period to be the best; the evening was better than the morning, and the midnight result was about equal to that of the morning—an order but slightly different from that of my own results. He also quotes Buch as having found (with the dynamometer) a low muscular power in the morning; greater after luncheon, and greatest after dinner.

Harley,[3] also making use of the Mosso ergograph, in experiments on himself, found the diurnal variations under ordinary conditions to be: maximum about 3 P.M. and minimum at 9 A.M. (his experimental day was only from 9 A.M. to 8 P.M.), as shown by Table IX., in kilogram-meters.

TABLE IX. VARIATIONS IN NORMAL MUSCULAR POWER—ERGOGRAPH (AFTER HARLEY).

Hour	9	10	11	12	1	2	3	4	5	6	7	8
Work	6.2	6.4	8.7	7.0	9.5	8.2	9.9	7.8	8.9	8.7	7.2	8.8

The agreement of this result with what has preceded is obvious.

Christopher[4] employed the ergograph for tests 90 seconds long every hour from 8:30 A.M. to 3:30 P.M., one day, on 1,127 schoolboys and girls. More intensive tests were made on four children of each sex. He concludes that

[1] 'Variations of Knee-jerk, etc.,' *Am. Jour. of Psych.*, **1**: 5–71. 1887.

[2] J. Joteyko, 'Rev. Générale sur la Fatigue Musculaire,' *L'Année Psych.*, **5**: 1–54. 1898.

[3] 'Effect of Sugar and Smoking on Muscular Work,' *Jour. of Physiol.*, **17**. 1894.

[4] 'Report on Child-study Investigation,' *An. Rept. of Bd. of Ed. of Chicago.* 1898–1899.

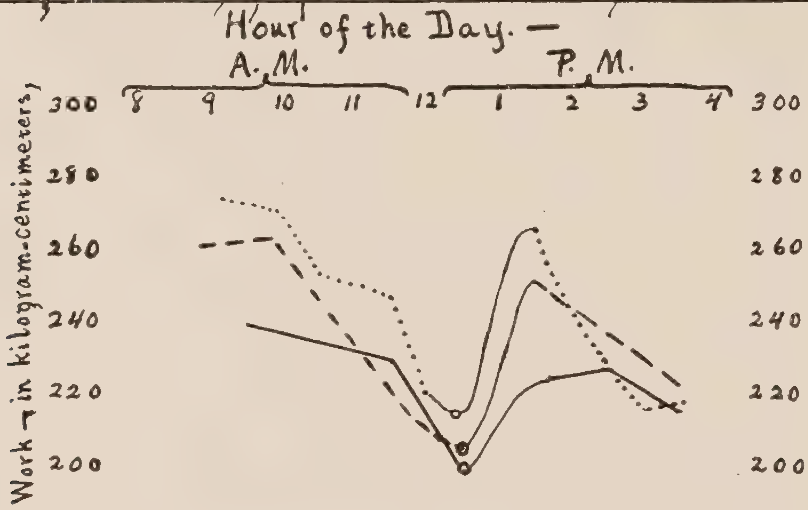
1. The extremes of endurance and fatigue are greater in the morning than in the afternoon.

2. Strength is not as great in the afternoon, but is better sustained than in the morning.

3. In children the intellectual capacity varies as the physical condition.

Smedley[1] repeated the experiments on six boys and six girls of another school and practically confirmed the other work, as reference to Fig. 3 will indicate.

Fig. III. — Ergographic Tests.— Chicago Schools.



Solid line = average record of 1121 pupils of Alcott School.
Broken " = " " " " 8 " " " " .
Dotted " = " " " " 12 " " Tennyson " .
First two after Christopher—Last, after Smedley.

These results suggest that fatigue may be a more influential factor with children than with adults and may modify the diurnal curve accordingly. This whole matter will be treated at length later.

Oseretzkowsky and Kraepelin,[2] using Mosso's type of ergograph, found that the average height of contraction (measuring the amount of performance) was greater at 2 P.M.; but the number of contractions (measuring the endurance) at 10 A.M. These experiments, being made only at the hours named, contribute only confirmatory evidence to what has already been produced.

Storey[3] reports work, with a modification of this type of machine, on students of Stanford University, number not given. The first

[1] 'Report on Child-Study Investigation,' *An. Rept. of Bd. of Ed. of Chicago.* 1899–1900.

[2] 'Ueber die Beeinflussung der Muskelleistung durch verschiedene Arbeitsbedingungen,' *Psych. Arbeiten,* **3**: 643 seq. 1901.

[3] Some Daily Variations in Height, Weight and Strength,' *Am. Phys. Ed. Rev.,* **6**. 1901.

series was from 8 A.M. to 6 P.M. and shows the maximum at 4 P.M. and minimum at noon—but slightly below the 8 A.M. figure. In a second series—details lacking—from 7 A.M. till 11 P.M., the highest point occurred at 9 P.M. and lowest at 7 A.M.

Subsequently,[1] for himself, he found that "there is a normal *decrease* in ability to do muscular work between 2 and 5 P.M." (p. 193). This must be a misprint, for at another place he says "the morning max. comes at or near 10 A.M and the afternoon max. at or near 4 P.M.," and this is borne out by his tables, which are, however, not always clear.

Very recently[2] he has made an extended study of the matter which, on the whole, confirms his earlier results and conclusions. Half the article describes the rather complex apparatus used—his own modification of the Lombard ergograph, employing weight or spring resistance, as desired. His method of exhibiting results is open to criticism, for only the roughest comparison of groups is possible, and that not of the best sort. How *much* was gained or lost is usually the most essential thing to know. The results show the number of times that gains or losses in power were found for the successive hours, when each was compared with the preceding. The unequal numbers of trials at the different periods show that the false assumption was entertained—alluded to before[3] as made by many authors—that incomplete records of some of the days represented give reliable data for such relational procedure as the problem involves. Storey himself, a well-trained subject, comes first in the table. A language student, 21 years old, taking no regular exercise, gave the results in the second division of the table. A law student and athlete, 21 years old, is reported in the third section, while three adult mechanics gave the results of the last section.

TABLE X. COMPARISON OF HOURLY ERGOGRAPHIC RECORDS—AFTER STOREY.

No. of Subjects.		6–7	7–8	8–9	9–10	10–11	11–12	12–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10
1	Gaining.		6	24	16	12	4	5	11	28	14	2	3	5	3	0	
	Losing.		0	1	5	4	20	1	3	1	6	16	17	1	3	5	
1	Gaining.	6	6					9						5	5	2	1
	Losing.	2	1					0						3	5	8	4
1	Gaining.				11		8		5		12		10				
	Losing.				1		6		10		3		4				
3	% of gains.		61		52		21				3						
	% of losses.								33				6		15		48

[1] 'Daily Variation in the Power of Voluntary Muscular Contraction,' *Am. Phys. Ed. Rev.*, 7. 1902.

[2] *Studies in Voluntary Muscular Contraction*, Stanford Press, pp. 60. 1904.

[3] See above, p. 2.

With the Upham dynamometer Storey then tested, in all, several hundred Stanford students by one grip before and one after an hour's gymnasium practise in classes at 10–11 A.M. (1,653 records for each hand); 11–12 A.M. (1,772); 3–4 P.M. (1,366); 4–5 P.M. (1,990); 5–6 P.M. (2,726). His main object was to ascertain the influence of gymnasium work on motor power, but, considering this work a constant factor, the above periods can be compared. The results are thus stated: "there is evidence of a morning period of muscular ability between 10 and 11 A.M.; a subsequent diminution between 11 and 12; a tendency to rise between 3 and 4 P.M.; about the same condition between 4 and 5; and finally there is evidence of a tendency to lose power between 5 and 6 P.M." (p. 49).

This, he truly says, verifies all the preceding work. He fails to call attention to the early morning degree of inefficiency, though its presence is indicated by the high gains at the 8–9 and 9–10 periods. These results being in such a form as to give no definite idea of the real quantitative difference of efficiency at the different hours can not be closely compared with the work of other authors, but the divergence between his results and mine lies almost wholly in the *extent* of the noon and night drops. As to the general form of the diurnal curve, they are alike.

The present writer also tested the strength of the grip, first using Collin's oval dynamometer. This instrument was also used in a set of leg-back tests, to be treated very soon. For convenience both results are incorporated in Table XI.

These figures point rather consistently one way, being similar to Storey's save in the particulars mentioned above.

My own individual order, of an early minimum and late afternoon maximum, is placed beyond all doubt by three other series. The first was for 30 days in autumn, under great regularity of external and subjective conditions. Five grips at each of 7 periods were taken. The second was also for 30 days, morning and night, 2 grips at each. The third was for 12 days, 11 periods and 2 grips at each. The last two were taken with the Narragansett dynamometer, registering higher than the Collin's instrument, which was used in the first series. The great amount of material secured enabled me, however, to transmute the results of the one into the unit of the others with but slight absolute error, that would not at all affect the relative standing of the periods. To eliminate practise effect, the first ten days' records of the first two series are omitted; no allowance was made in the third, which immediately succeeded the second in point of time but stands second in the table.

TABLE XII. MUSCULAR POWER—HAND DYNAMOMETER.

Subject I.	No. of Grips.	7:00 A.M. Kilos P.E.	8:30 A.M. Kilos P.E.	10:00 A.M. Kilos P.E.	11:30 A.M. Kilos P.E.	1–1:30 P.M. Kilos P.E.	3:00 P.M. Kilos P.E.
Right...	100	60.7 0.17		63.5 0.16		64.9 0.18	
	24	60.8 0.27	6.30 0.26	65.2 0.23	66.2 0.22	66.1 0.32	66.2 0.28
	40	60.2 0.23					
Left.....	100	56.6 0.18		59.3 0.18		60.7 0.18	
	24	52.2 0.36	54.1 0.30	56.0 0.33	58.2 0.28	58.3 0.37	58.1 0.32
	40	54.1 0.19					

Subject I.	No. of Grips.	4–4:30 P.M. Kilos P.E.	6:00 P.M. Kilos P.E.	7–7:30 P.M. Kilos P.E.	9:00 P.M. Kilos P.E.	10–10:30P.M. Kilos P.E.	11–12:00P.M. Kilos P.E.
Right...	100	66.2 0.19		63.7 0.18		61.7 0.17	60.7 0.21
	24	67.3 0.25	69.0 0.30	67.1 0.22	66.0 0.23	64.2 0.25	
	40						63.9 0.33
Left.....	100	61.7 0.20		59.5 0.17		58.0 0.17	56.6 0.22
	24	59.2 0.24	60.1 0.22	58.0 0.35	56.3 0.31	54.1 0.31	
	40						57.7 0.19

Attention is here called to Table V., showing various groups of males and females tested as to forearm strength. It will be noted that the men did almost uniformly better in the afternoon than in the morning, while the females were about evenly divided. How these results are to be construed has already been mentioned and needs no fuller comment at this point.

The larger muscular groups are not so readily tested. At an international meeting of the University Physical Directors at Princeton, in December of 1903, an attempt at agreeing on the best gymnasium methods of testing general muscular efficiency was unsuccessful, and it was decided to temporarily continue the old ones with certain modifications. This suggests the difficulty of getting adequate tests.

Floor Dip. This was meant to test the arm muscles mainly, and consisted in extending the (rigid) body parallel with the floor, on toes and hands, and then alternately raising and lowering it by the arms as rapidly and as often as possible, efficiency being measured by the number of times it was thus completely raised. The tests were on myself for twelve days, but the first three were omitted and a small correction made on the rest for practise. The results are decisive for the periods shown.

7 A.M., 17.2 (P.E., .15); 12 M., 21.3 (.34);
5 P.M., 22.6 (.28); 10 P.M., 19.3 (.15).

Floor Squat: a test for leg muscles in which the subject alternately squatted and raised himself 100 times as rapidly as possible. An extended effort to measure the deficiency present by the shortening of the time the subject could hold his breath after the exercise,

TABLE XI. MUSCULAR POWER—HAND AND HAND-FOOT DYNAMOMETERS.

Each Hand Alone.		7–9 A.M.				12–2 P.M.				4–6 P.M.				9–11 P.M.			
		Right.		Left.		Right.		Left.		Right.		Left.		Right.		Left.	
Subject.	Grips.	Kilos.	P. E.	Kilos.	P. E.	Kilos.	P. E.	Kilos.	P. E.	Kilos.	P. E.	Kilos.	P. E.	Kilos.	P. E.	Kilos.	P. E.
I.	60	45.3	.24	42.0	.27	47.1	.22	44.2	.29	49.2	.21	45.1	.25	46.1	.23	43.3	.21
II.	48	53.3	.23	44.1	.29	56.6	.25	47.6	.32	56.6	.29	46.6	.32	54.0	.32	45.2	.31
III.	36	50.0	.52	42.2	.61	51.2	.49	45.1	.64	53.1	.47	44.3	.56	52.3	.54	43.2	.59
IV.	40	52.2	.29	43.7	.58	54.5	.21	45.8	.51	54.7	.26	46.6	.35	52.8	.27	43.5	.61
VI.	50	54.2	.48	47.7	.62	55.6	.44	46.9	.54	54.7	.50	48.1	.61	55.4	.43	48.0	.59
Average.	47	51.0	.35	43.9	.47	53.0	.32	45.9	.46	53.7	.39	46.2	.42	52.1	.36	44.6	.46
A	42	32.0	.20	28.7	.14	—	—	—	—	33.2	.20	29.3	.22	32.1	.17	28.0	.19
B	32	28.7	—	26.2	—	28.0	—	25.1	—	27.0	—	25.3	—	—	—	—	—

Each Hand and Foot.		7–9 A.M.				12–2 P.M.				4–6 P.M.				9–11 P.M.			
Subject.	Pulls.	Right Kilos.	P. E.	Left Kilos.	P. E.	Right Kilos.	P. E.	Left Kilos.	P. E.	Right Kilos.	P. E.	Left Kilos.	P. E.	Right Kilos.	P. E.	Left Kilos.	P. E.
I.	30	76	0.9	77	1.0	84	1.1	82	1.0	85	1.0	82	1.1	79	0.9	77	0.9
V.	36	78	1.2	76	1.1	85	1.1	82	1.3	84	1.2	81	1.2	78	1.0	75	1.0
A	24	44	0.7	42	0.7	46	0.9	44	0.7	—	—	—	—	42	0.8	41	0.8

Both Hands and Feet.		7–9 A.M.		12–2 P.M.		4–6 P.M.		9–11 P.M.	
		Kilos.	P. E.	Kilos.	P. E.	Kilos.	P. E.	Kilos.	P. E.
I.	30	137	1.7	147	2.1	150	1.8	142	1.9
V.	36	128	2.3	140	2.1	138	2.0	128	2.1
A	24	74	1.1	—	—	75	1.8	72	1.3

or by the increase in pulse rate, proved fruitless. Then forty-pound dumb-bells were held in the hands and quick fatigue secured by squatting as before, in a short series. The results were too meager for quantitative expression but quite similar in tendency to those of the floor dip for arm muscles.

Hand-foot Dynamometer: designed to test combined arm, back and leg strength. It is made up of the Collins oval dynamometer, having a kilo scale for use when the instrument is pulled endwise and equipped with the necessary handle and foot attachments for pulling. A short length to the whole, 14 inches, insured full use of the leg muscles as the subject sat on the floor and pulled. The operations were: right hand and foot, left hand and foot, and finally both hands and feet, three times each period. The results are shown in Table XI., while Table V. gives some results for two Filipino groups, with whom Tiemann's pulling apparatus was used, also registering in kilos. There is no radical discrepancy between these and preceding results. Though the P.E. is sometimes large, it is clear from the whole course of the figures that the middle of the day, including the afternoon, is a time of greater muscular strength than either morning or evening.

The curve of strength efficiency seems, therefore, well established for the following course, and this probability will be strongly reinforced below by further data: a beginning minimum in early morning, a fairly rapid rise till 11, a level or slight decline till 1 P.M. ($\pm$ 1 hour), an increase to the maximum at 5 ($\pm$ 1 hour), thence a fall till bedtime. Explanation of this is attempted in Part D.

(*b*) *Comparative Functioning of Muscle Groups.* As to whether the work of very small groups can be taken as indicative of the general muscular condition, an assumption long and often made with little attempt at proof, it appears from the above tables that the assumption is in reality well founded. In order to avert confusion, attention was not called to this point in passing, nor to the one succeeding, and their verification must, therefore, be retrospective on the part of the reader.

(*c*) *Bilateral Symmetry.* Regarding this matter, a review of Tables V., VI., VIII., XI. and XII. will disclose the fact that, although fluctuations occur, yet as a whole the figures show the same general course of efficiency for both sides of the body. The other evidence obtained agrees on this point. Lombard[1] with the ergograph noted that the strength may be greater on one side when least on the other, but that 'the major variations occur simultane-

[1] 'Fatiguing Voluntary Work,' *Jour. of Physiol.*, **14.** 1893.

ously on the two sides' (p. 114), and Storey, in a work already cited, with many subjects found the same.

c. General Motor Control. Experiments with the ataxiagraph to determine relative steadiness in standing for different times of day, and with the automatograph to determine changes in involuntary movement, were planned but could not be carried out for lack of time, though the author is convinced by rough, tentative tests in balancing, etc., that the field is fruitful for this problem and would throw light on the other results.

d. Complex Motor Activity. Of course there is no jump between the following and what has preceded. Attempt was made to get data on activities of a more comprehensive character, first by means of a questionnaire designed particularly for physical directors and athletes, and containing questions as to what their experience would lead them to say on the matter of recurrent periods of varying ability, and their objective grounds for the opinion. The few replies that have been received are suggestive.

Mr. J. G. Lathrop, Physical Director[1] of Schools at Southboro, Mass., says: "I have never considered it possible for me or any one under me to do as good performances in the morning as in the afternoon and that, so far as I know, is the experience of others. This, I consider, applies to any form of athletic work."

Dr. G. L. Meylan, Medical Director of Columbia Gymnasium, after long experience as physical director, corroborates these words of Mr. Lathrop. Mr. Davis, his assistant, holds the same decided opinion, and both describe various performances in substantiation thereof.

Miss Louisa Smith, Director of the Bryn Mawr Gymnasium, replied thus: "We have athletics only in the afternoon and no comparisons can be made. But I have noticed this: when we used to have both afternoon and evening classes, the students of the afternoon classes did the better work in educational gymnastics. In our physical examinations, too, I have noticed that those strength tests that are taken in the early part of the day average better than those taken between 9 and 10 in the evening." Here we find the same as set forth above for females.

Mr. C. H. Robinson, Harvard athlete, 21 years old, submits this: "Last winter [1903] I competed in the shot-put at the Boston Athletic Association games and the best distance I could get was 40 feet. These games came Saturday night. On the Monday following I returned to my practise in the afternoon and easily reached

[1] Now track-team coach at Harvard University.

44 feet. I have found this same fact true when I worked in the morning." He thinks the time of the maximum is determined by that of practise—which is only partly true.

Mr. T. G. Meier, another Harvard athlete, 23 years old, says that he "has never noticed any particular difference between morning, afternoon and night scores"; but mentally the morning seems best, with periods of lesser alertness after lunch and dinner, and then an efficient one from 8 P.M. to 12 M. This case must be noted as an apparent exception.

Under the present heading will also be discussed certain observations of *manual labor in factories,* made by the author at various times through several months. The main results are given in Table XIII., which reveals also the chief conditions. But some words must be added in fuller description of each group.

The first group[1] is the most noteworthy, by reason of the regularity of the work, the basis of pay, and the number of hours per day. Its members were all experienced stitchers except the last, in whose case a correction was necessary for practise effect. They worked at top speed, presumably, as long as the material was supplied by the 'gathering machines', which was about 45 or 50 minutes out of each hour. That is, all were obliged to stop these few minutes while the supply 'piled up' for the succeeding hour's run. At 12, 5 and 9 P.M. they worked only half an hour. Other than this the individual stops were insignificant. One was sick four days, another transferred to other work for a day, etc., so that although observations were continued eleven days no one is reported for the full time. The first day's work was disregarded entirely, as it was found to be much affected by the initial experience of being observed. The same was true with the second group. Ordinarily, 120 magazines at a time were given to each worker, while, on my part, the time required to do this number, or any multiple of it, was taken just as often as it could be caught exactly, and subsequently reduced to the form shown in the table.

In the second group the first two girls were experienced and piece-workers; the rest were inexperienced and worked partly by piece and partly by time, hence it was useless to attach P.E.'s to their averages. When paid by the thousand, they did from 30 to 60 per cent. more than when paid by the day. Through the kindness of the foreman[2] the work was given to them in even hundreds; otherwise it would have been impossible to get correct records of

[1] The work was the binding of a 900,000 edition of *Everybody's Magazine* by the Trow Directory Co., New York City.

[2] These observations were made at Dennison and Sons, New York City.

more than two girls at a time. In fact, several days were devoted to the first two before the above arrangement was instituted, and tab was kept of the individual holders made. After that the time per 100, for each of the eight, was taken as frequently as it could be caught, together with the corresponding time of day. More labor than for the first group was required to reduce these data to a uniform basis. The ten-minute basis was chosen to agree with the first group, where it had been selected to avoid the use of four-place numbers for the hour. During most of the time the work was distributed to the workers by the author, which insured better control of the conditions.

The third group covers cases where reliable records for only one or two days were secured.[1] In the pursuit of this phase of the general problem much valuable time was wasted in seeking opportunity for suitable observational work,[2] but the trouble did not end there. Some people naturally object to being watched so closely and especially when on time-work. This would not be in evidence till after the first day. In several instances records were thrown away for wilful 'soldiering'. To make these results from various sorts of work comparable it was necessary to treat them as indicated in the table. That is, + 11 for the first subject means that she was, between 8 and 9 A.M., 11 per cent. above her average efficiency for the whole time observed.

TABLE XIII. FEMALE INDUSTRIAL LABOR.

I. Magazine Wire-stitching. — Average Number Done per Each 10 Minutes of the Hour. — Piece-rate Basis of Pay.

Subj.	Age.	Days.	Nights.	8-9 A.M.		9-10		10-11		11-12		12-1 (12:30)	
				No.	P. E.	No.	P. E.	No.	P. E.	No.	P. E.	No.	P. E.
1.	27	9	4	148	1.38	156	1.09	158	0.47	155	1.39	157	1.06
2.	24	9	3	144	1.42	156	1.54	155	2.71	155	2.32	152	1.79
3.	20	10	5	146	1.81	153	1.43	153	0.88	150	1.26	158	1.23
4.	32	10	3	138	1.03	149	0.79	150	1.04	156	1.11	156	1.51
5.	20	9	3	128	2.62	140	2.33	142	2.02	141	2.32	149	1.43
6.	26	10	4	109	0.85	110	0.71	108	1.14	109	0.82	110	1.05
7.	23	5	3	110	1.24	115	1.59	119	2.48	111	2.28	118	2.34
8.	19	7	3	111	1.67	114	1.94	118	2.02	117	2.41	115	2.79
Av.	24	8.6	3.5	129	1.59	137	1.43	138	1.59	137	1.74	139	1.65

[1] For these records I am mainly indebted to J. English and Sons and Dennison and Sons, New York City.

[2] What obstacles one encounters on this score is suggested in the following: 5 each of apparently the best representatives of 20 lines of manufacture were selected and a carefully written letter sent to each, stating aims and needs, together with stamped addressed return envelope. Of these 100 letters, 6 were returned unopened, 7 unfavorably answered, 9 favorably answered, and 78 ignored entirely. Of the 9, 5 factories were distant from New York, 3 were unfit for the work, and 2 were used.

Subj.	Age.	Days.	Nights.	1-2 P.M.		2–3		3–4		4–5		5–6 (5:30)	
				No.	P. E.	No.	P. E.	No.	P. E.	No.	P. E.	No.	P. E.
1.	27	9	4	156	0.90	158	1.42	152	0.81	153	1.64	154	1.71
2.	24	9	3	157	2.62	162	1.23	158	2.90	162	2.91	154	1.79
3.	20	10	5	156	1.02	156	1.53	151	1.56	153	1.51	156	1.11
4.	32	10	3	155	1.19	151	1.01	147	1.07	152	1.00	151	0.97
5.	20	9	3	143	2.40	144	2.21	143	1.87	143	2.43	147	2.60
6.	26	10	4	113	0.97	113	0.85	113	0.62	108	0.78	106	1.07
7.	23	5	3	126	1.24	125	2.27	121	2.49	114	3.23	112	3.42
8.	19	7	3	111	1.57	112	1.66	112	1.82	112	2.28	105	1.77
Av.	24	8.6	3.5	140	1.49	140	1.52	137	1.64	137	1.97	136	1.80

Subj.	Age.	Days.	Nights.	6–7		7–8		8–9		9–10 (9:30)	
				No.	P. E.	No.	P. E.	No.	P. E.	No.	P. E.
1.	27	9	4	157	1.12	158	1.01	163	0.93	164	1.28
2.	24	9	3	163	2.86	160	0.62	158	0.00	159	0 62
3.	20	10	5	156	1.58	156	1.72	157	1.31	157	1.63
4.	32	10	3	160	3.82	155	2.41	152	1.12	162	3.75
5.	20	9	3	148	3.48	148	2.29	142	2.61	140	3.56
6.	26	10	4	117	2.06	116	2.00	116	1.60	121	1.92
7.	23	5	3	121	2.51	115	2.39	115	2.35	111	2.43
8.	19	7	3	110	1.78	118	1.39	114	2.83	113	2.71
Av.	24	8.6	3.5	141	2.40	141	1.73	140	1.60	141	2.24

II. Making Paper Coin-cases. — Average Number Done per Each 10 Minutes of the Hour.

Subj.	Age.	Days.	Pay Basis.	8–9 A.M.		9–10		10–11		11–12		12–1 (12:30)	
				No.	P. E.	No.	P. E.	No.	P. E.	No.	P. E.	No.	P. E.
1.	18	10	Piece	94	1.66	97	1.21	94	1.29	92	1.42	89	1.90
2.	16	9	"	74	2.10	79	1.14	76	0.81	72	0.56	71	1.99
3.	16	6	Piece and Time Basis	47		48		46		46		47	
4.	17	5		61		61		62		58		61	
5.	16	4		49		50		48		43		39	
6.	16	3		50		41		43		45		45	
7.	15	5		52		50		49		50		52	
8.	14	3		40		43		41		39		36	
Av.	16	5.6		58		59		57		56		55	

Subj.	Age.	Days.	Pay Basis.	1–2 P.M.		2–3		3–4		4–5		5–6 (5:30)	
				No.	P. E.	No.	P. E.	No.	P. E.	No.	P. E.	No.	P. E.
1.	18	10	Piece	97	1.56	97	2.11	94	1.98	90	1.16	87	1.49
2.	16	9	"	73	1.73	70	1.34	70	1.42	73	1.55	77	1.64
3.	16	6	Piece and Time Basis	51		50		44		43		42	
4.	17	5		59		53		51		50		52	
5.	16	4		49		47		44		43		42	
6.	16	3		48		47		46		44		34	
7.	15	5		47		44		45		45		42	
8.	14	3		41		40		43		36		33	
Av.	16	5.6		58		56		55		53		51	

III. Numbering Checks and Ledger-lines. — Hourly Per Cents. Above or Below the Day's Average Rate.

Subj.	Age.	Days.	Nights.	8–9 A.M. No.	9–10 No.	10–11 No.	11–12 No.	1–2 P.M. No.	2–3 No.	3–4 No.	4–5 No.
1.	24	2	Time Basis	+ 11	+ 9	+ 4	— 7	— 15	+ 1	— 6	+ 3
2.	19	1		— 19	— 10	0	+ 14	+ 18	+ 9	+ 2	— 14
3.	21	1		+ 8	+ 10	+ 6	+ 6	— 12	— 2	— 12	— 4
4.	32	1		— 4	— 3	— 2	+ 4	+ 6	— 3	+ 3	— 1
5.	18	1		— 12	+ 16	+ 32	+ 31	+ 9	— 18	— 25	— 32
6.	36	2	Piece	— 6	— 0	+ 6	+ 3	0	0	— 3	0
Av.	25	1.3		— 3.7	+ 3.7	+ 7.7	+ 8.7	+ 1.3	— 2.2	— 6.8	— 8.0

In considering these figures, if one were to look only at the total averages, it would not be very troublesome perhaps to read off what they most probably meant. That would not exhaust the facts, however, and might be misleading. From this standpoint it might be said that the first group shows increasing efficiency till 3 P.M., then a decrease till 5:30, then a marked recovery and maximum rate till 9:30; in the case of the second, a morning maximum, followed by decrease till 12:30, then a sharp recovery and a succeeding gradual descent; and in the third, a gradual increase to a noon maximum, and then a more rapid decrease to an evening minimum. Of the individual curves of a group, a rather large proportion follows the respective group curve. Thus, 1, 2, 6, 7, in I.; 1, 4, 5, 7, 8, in II.; and 2, 5, 6, in III. This is more evident in the plotted curves, of which only those of the wire-stitchers were drawn.

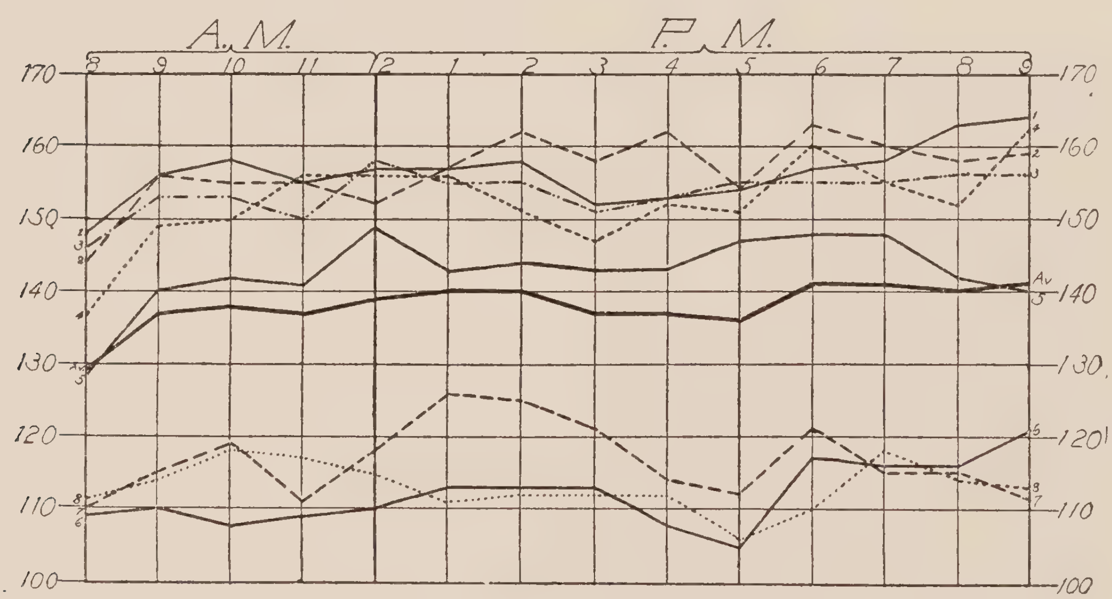


FIG. 4. Magazine Wire-stitching by Females—see Section 1 of Table XIII.

What specifically need attention are the fluctuations occurring at the first, fifth, tenth and fourteenth periods. In the first, 17 subjects show low efficiency and only 5 show a relatively high one. This is further confirmation of what has already been found for this

period. A trained 'observer' for Gunn, Richards & Co., of New York City—their business is to introduce into factories new systems of shop management and production, and in the establishing of 'unit times' for the separate operations involved in the making of many different articles they have made thousands of observations[1] on the speed of work—says this morning inefficiency, also noted by himself, is 'due to the absence of the foreman.' But in the present instances this condition never occurred and could not at all be the true reason. In addition, piece-workers would be supposed to have the same prime incentive to maximum activity present at this as at any other period of the day.

At the 12:30, 5:30 and 9:30 periods several factors figure very effectively. Here the most pronounced fatigue tends to be offset by what has been termed 'end-glow'—the strenuous attempt to increase the output to the utmost limit at the last moment. These features are so characteristic that no correct interpretation of the curves is possible without their consideration. The periods immediately succeeding those named are influenced not only by rest and food, but also by the social intercourse which has intervened since the last work period. Reference is again made to Part D, where general treatment of these factors is preferably taken up.

With these things in mind, and due reference to age and pay-basis, some definite conclusions can be formulated from the individual records.

First, piece-workers tend to follow the end-glow type and time-workers the fag-end type. In group I., of the 24 cases at the three periods mentioned, 15 show the typical trait, whence it is safe to judge that at least half the rest are affected by it, to a lesser degree. Of the 16 cases in group II., 7 are of this type and 6 of them were directly due to piece-work.[2] And even the exceptional case of subject 1 is fully accounted for by the fact that she usually set 4,000 as the limit for the day's work and was able to reach this without special effort, thus becoming *really* a time-worker. Of the 12 cases in group III., 5 follow the type in question, 1 of whom was a piece-worker. The influence of my presence would be more apparent in this group and would naturally be more pronounced at these than at other periods, since few can refrain from endeavor to 'put the

[1] The best stop-watch (also time-book) for all classes of observational work, of which the author is aware, is one designed for this purpose by S. E. Thompson, C.E., West Newton, Mass.

[2] It should be noted here that the period prior to each of the three in question may also be affected, because the arbitrary limitation of the periods allows only 25 or 30 minutes to each of these three.

best foot forward'; and in morning than in afternoon, of the one day. Personal knowledge of the workers suggests that at least five of the nine failures in the first group to follow the prevailing type were due to physical inability to maintain the requisite pace. Subject 7, who was sick four days, could not work up to 5:30 and 9:30 climaxes, after showing a decisive tendency to end-glow at the 12:30 period. Subject 8 was youngest and most inexperienced and on both accounts was unprepared to meet the physical strain necessary to make these special bursts of speed. For the same reasons, these two subjects fail to make a night gain where the other six do. As to the time-workers, the evidence seems as conclusive. The last six subjects of group II. were paid by the thousand for two days, and the records made then tend to overbear those of the other days. In but 1 of the 16 cases did there seem to be a naturally strong wind-up. The cases in group III. can not be said to alter these conclusions materially, as they have not the same weight even if they evinced contrary results.

Second, it seems reasonable to believe that endurance as dependent on maturity is much involved. In fact, it is impossible to say how much the falling off in the production of the time-workers at the stated periods is to be accounted for on the ground of indulgence of the feelings of fatigue, due to lack of the same incentive to high activity that piece-workers possess, and how much is to be allowed for the fact of physical inability due to immaturity and consequent real fatigue. To the author, the results for group I. seem due to the basis of pay in its stimulative aspect, while for group II. they seem considerably due to immaturity, save in the first two cases. It is not unworthy of note, in this connection, that of the five cases of this group mentioned above as showing high efficiency in the early part of the day, three are the youngest of the eight, all of whom have proportionately higher records at this time of day than do the adults. Their curve as a whole follows quite closely that found by Christopher for the Chicago school children, seen in Fig. 2 above.

Neither piece- nor time-workers can be thought to exhibit what would be the curve of earnest, ordinary work; but the former conceivably resemble the top extreme of such a group, where the maximum product is reached, while the latter would represent the bottom extreme, where exists a minimum of accomplishment and a maximum of yielding to the feelings of fatigue. It would scarcely be worth while to carry the analogy to the extent of determining the theoretical median or modal curve of such a group, to express its general tendency. Likewise, it is scarcely worth while to seek gen-

eral 'type' curves of ability. That is, there is danger in the smoothing-out process which leaves to curves only their coarsest changes. It is the positive tendency of all present-day scientific methods of gathering, registering and measuring data to subdivide phenomena more and more in order to get a more accurate judgment of the whole fact in the light furnished by the more detailed and exact definitions of the separate parts. This is quite a contrary operation throughout to the process of smoothing.

This danger can be thus illustrated: an increase of 20 per cent. in efficiency at a certain hour may be entirely due to a waking nap in the preceding hour, where a loss of only five per cent. was sustained by reason of the doziness. We should likely call the first mentioned change worthy of notice and the other not, if smoothing were in mind, yet in reality the one could not occur without the other and indeed the results might, in its absence, be just the reverse. This is not purely hypothetical, since in my own case a partial loss of consciousness for five minutes in the afternoon frequently has a very appreciable mental effect for the better, though a long and real nap has the opposite effect.

There is some satisfaction and there may be some practical advantage in having such gross 'types' of endurance, etc., but they hold the same doubtful position as to actual explanatory desiderata that all other generalities occupy. It probably will be agreed that this table does emphasize the two types described, but it is easy to find deviations in the individual curves. Others than these two are hard to locate and depict. Kraepelin describes five or six fatigue 'types', but is enabled to do so merely by grace of having used but four hours a day in his tests: the curves become more than proportionately complex when twice or thrice that length of time is utilized, and the number of individuals falling under each is correspondingly reduced.

Attention has already been called to the early inefficiency in group I.; it is now directed to the more notable fact that the highest point is reached at night by six out of the eight. That this would remain as the normal condition in regularly continued labor is not likely (each was allowed to work only every other night during the two weeks' continuance of the job). While the results will, therefore, not permit the temporal fixing of maximum performance, they do serve to introduce a point of considerable practical and psychological interest. That it was possible, after a full day of severe effort, to increase the output so notably and so long suggests how nicely the organism comes to be adjusted to the drains likely to be

made upon it. It might be truer to say that there is in the early part of a long day's work an organic or at least involuntary checking of the tendency to overdraw the store of available energy. Anyway, we seem never to reach the absolute maximum of exertion possible to us. Not only end-glow, but a number of other things, especially in the second group, caused marked increase of ability. It is worth knowing whether such induced bursts as the latter are clear gains or are counteracted by subsequent inefficiency. The solution of this question does not appear from our data, because of the many unexcluded factors.

The wire-stitching done by the first group does not require any special accuracy of movement, but decidedly involves speed. Here, again, is suggested, as in connection with the tapping tests, the possibility of nervousness increasing the rapidity of certain sorts of movement that do not require precise muscular coordinations. Women presumably are more 'nervous' than men, and hence it becomes inconceivable from the physiological standpoint that these could have worked all day near their speed limit and not have been neurally disorganized at the end. Their period of greatest speed of work thus coincided with their probable period of greatest nervousness.

3. *Brief Summary.*—The necessity is shown of keeping separate the rate, accuracy and strength of movement and not lumping everything as merely 'physical ability', while the further division of the first two for different types of simple and complex movement is strongly suggested. Just what diurnal schedule each of these follows has not been fully demonstrated, but some points have been definitely fixed. As to strength (not meaning endurance), there is ample reason for believing that most commonly the first morning power is relatively low, but subject to a fairly rapid rise till about 11 A.M., when there is manifested a slight backward tendency till 1 P.M. ($\pm$ 1 hour), then a gradual ascent to the maximum between 3:30 and 5:30, whence there is a much more gradual descent till bed-time, when a second minimal point is reached—with adult males. Females tend to push this curve back at every point, and children still farther, apparently due to their greater liability to physical exhaustion; men have more strength and are less likely to use it. As to rate and accuracy of movement, there is still found the deficiency at the extremes of the day, but with a marked tendency to more accuracy efficiency toward the morning end and rate efficiency toward the night end, and these tendencies are accentuated as the test for accuracy is more complex and that for rate more simple. Strength and speed may be increased by a highly nervous state, but

accuracy is oppositely affected. Female shop operatives, in addition to confirming some of the preceding points, tend as piece-workers to the end-glow type when approaching intermissions, and as time-workers and children to the opposite extreme, while both classes manifest ability to increase their product considerably, under special stimulation, at any portion of the day and despite the fact of previous hard work.

C. COURSE OF MENTAL EFFICIENCY

I. The Simpler Mental Activities

This field, having so much in common with the last, has its peculiarities, nevertheless, which serve to introduce the marked difficulties characterizing the study of psychic life. It was not because the ancients found the latter too easy a problem to be worthy of notice that scientific attention was turned outwards, but rather because it was so fine-spun and intangible as to escape much notice. The 'popular mind' is yet quite free from introspective questionings, and any such ignorance of the presence of a problem is likely to be indicative of its difficulty. Aside from any spiritual considerations which might lead to the study of psychology as the science of the soul, there is every reason to believe that the mind's more immediately utilitarian use as a tool or means for meeting the various needs of the higher life in general—volitional, cognitive, esthetic, or whatever one may call them—will increasingly force itself to the front in one aspect or another. When it comes to determining the efficiency of this tool at different periods of the day, for the ends mentioned, the more radical complications of the problem emerge into view. It might be said that the last section had, on its mental side, most to do with volition; that the present would likely deal mostly with cognition; and the next, involving feelings of fatigue, etc., would touch upon emotion. With finer psychological analysis, it is seen that this program, even if fully realized experimentally, would still cover the field only in the grossest sense.

1. *Attention*

The tests of the fluctuation of attention, that Wiersma[1] first used and Pillsbury[2] repeated, seem rather tests of the senses employed than of attention itself. For instance, a certain weight was placed on a cork disk, of the same size, on the back of the hand, and the just perceptibly different weight was then determined, as also the one distinguished with certainty. Between these two limits six weights of equal degrees of difference were used, the test of attention being the length of time that each of these could be distinguished from the

[1] 'Untersuchungen über die sogen. Aufmerksamkeitsschwankungen,' *Zeitschrift für Psych. u. Physiol.*, pp. 179–198. 1902.

[2] 'Attention Waves and Fatigue.' *Am. Jour. of Psych.*, **14**: 314. 1903.

first as standard. For light and sound stimuli, six shades of gray and six gradations of sound were determined by the same principle as for pressure. Why it might not be a fatigue coefficient that is here obtained, where the senses are thus exercised, is not clear. Wiersma's tests covered three days with each subject. Pillsbury used only the grays in his repetition of the experiment. Table XIV. gives the results of both authors.

TABLE XIV. ATTENTION—PER DIFFERENT SENSES—WIERSMA, PILLSBURY.

Subject.	Test.	Morning.			Noon.			Afternoon.			Night.		
Wiersma.		Time.	M.V.		Time.	M.V.		Time.	M.V.		Time.	M.V.	
H	Pressure.	204.6	10.9					239.5	8.9		161.9	14.1	
W	"	201.0	6.1					251.1	3.0		283.5	1.7	
"	Light.	180.0	—					228.4	—		255.8	—	
"	Sound.	217.2	—					235.4	—		256.1	—	
Male nurse.	"	217.2	5.8					209.2	6.2		216.0	5.3	
Female nurse.	"	241.6	1.7					248.0	1.8		242.0	4.6	
Female nurse.	"	202.2	4.8					215.0	4.4		197.0	3.6	
Pillsbury.		No.	V/I	Sum.	No.	V/I	Sum.	No.	V/I	Sum.	No.	V/I	Sum.
P	Light.	300	2.4	9.6	245	2.5	8.5	337	2.6	8.2	365	1.6	7.5
H	"	287	3.4	9.4	230	2.6	8.7	285	3.3	9.3	300	2.9	9.0
G	"	249	1.2	8.9	181	1.3	8.9	265	1.2	8.4	377	1.2	8.4
W	"	275	1.5	5.4	196	1.6	6.3	—	—	—	281	1.5	5.1
F	"	73	5.0	18.9	37	4.7	18.2	79	3.4	13.4	63	4.5	18.8
K	"	38	1.6	13.5	42	1.9	14.4	41	3.4	14.6	33	5.6	22.0

No. = number of waves measured.
V/I = ratio of visible to invisible periods.
Sum = length of attention wave.

Wiersma is uniformly worst in the morning and best at night, while H has another order. It is strangely concluded that those of little mental training do not show *definite* variations and that these are due to general practise in mental work. A tendency in students to raise the night-end of efficiency may exist, but his subjects are too few and incomparable, and the results too discordant, to allow such an inference.

Pillsbury experimented on six subjects from one to six days. The first three records are obviously more reliable than the last three. With the exception of K (Külpe), who was a very strong night-worker, they point to a morning maximum and a night minimum in efficiency of attention. Pillsbury says that Slaughter and Bonser independently have found the attention wave to correspond to the Traube-Hering wave-length for blood pressure. This suggests a correlation with the diurnal variations in pulse and respiration

rates, which Galloway, in an unpublished investigation, finds really to exist.

It is not easy to see how fatigue effects could fail to operate in such protracted experiments with senses where, according to the prevailing idea, it is wont to appear quite early. The main fact measured would then have been sensory more than attentional, as intimated above. The difference of opinion may be merely definitional.

Lobsien[1] refers to some work by Schuyten, of Antwerp, on changes of attention in school children eight to ten years old, carried on for a school year—to determine atmospheric effect. At four periods of the day the number of times in five minutes they involuntarily raised their eyes from an assigned reading was noted. The results having a bearing here may be briefly stated thus: "The attention of school children diminishes from 8:30 to 11 and again from 2 to 4; is greater at 2 P.M. than at 11 A.M., but always less than at 8:30 A.M." Using the same method, Lobsien found the following results:

TABLE XV. VARIATION OF ATTENTION OF SCHOOL CHILDREN—AFTER LOBSIEN.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
A.M.	64	59	57	55	47	45	39	—	—	52	55	62
P.M.	59	55	57	52	49	47	42	—	—	50	51	58

Numbers mean per cents. of pupils not raising the eyes.

It will be seen that the morning or afternoon is the better according to the time of year, morning being more favored on the whole. This method seems better than the preceding, is simple and easy of application and measurement. The results are more concordant, possibly due to age, as well as more reliable.

2. *Discrimination*

For testing discrimination of letters, I used, in most of the series, a printed form of 500 capital letters—100 A's and 16 each of the other letters of the alphabet intermixed in irregular order. By some of the subjects, 1 of these 16 letters was marked out each period; by others, more than one. The marking out was done as rapidly as consistent with correctness and was timed by a stop-watch. The most conspicuous letters were not used, and the rest were so arranged that each occurred once in each period every three days, thus weight-

[1] 'Schwankungen der psychischen Kapazität,' *Pädag. Psych.*, V. Bd., 7 Heft. 1902.

ing each period alike as to the varying difficulty of different letters. The average time and its P.E., and the average number of omissions are shown for each subject in the following table:

TABLE XVI. DISCRIMINATION OF LETTERS—LETTER BLANK.

Subject.	No. of Days.	7–9 A.M.			12–2 P.M.			5–7 P.M.			9–11 P.M.		
		Time.	P.E.	Omis.	Time.	P.E.	Omis.	Time.	P.E.	Omis.	Time.	P.E.	Omis.
I. 1 letter	14	58.5	0.76	1.2	54.8	0.69	1.3	54.8	0.57	2.3	59.0	0.62	1.4
II. "	12	63.8	1.11	0.3	60.3	1.23	0.6	63.4	1.36	0.2	66.1	1.57	0.7
III. "	12	42.0	0.69	0.6	41.0	0.74	0.7	44.0	0.53	0.7	44.5	0.61	0.9
V. "	12	71.8	1.03	0.8	60.7	0.73	1.3	63.6	1.21	1.1	70.6	0.68	1.3
VI. "	11	42.5	0.43	2.3	41.3	0.70	3.0	40.5	0.70	2.5	40.2	0.70	2.2
Average	12	55.7	0.80	1.0	51.6	0.62	1.4	53.5	0.88	1.4	56.1	0.84	1.3
I. 1 letter	14	58.5	0.76	1.2	54.8	0.69	1.3	54.8	0.57	2.3	59.0	0.62	1.4
2 letters	10	84.8	1.00	3.9	76.3	0.91	4.2	77.1	0.70	5.5	81.6	1.36	4.2
3 "	10	112.2	1.19	5.1	106.0	1.04	5.6	108.1	1.91	5.6	116.6	2.05	6.1
4 "	8	141.5	1.26	5.9	131.6	1.99	6.4	132.4	1.25	7.6	140.0	1.63	7.1
Average	10	99.2	1.05	4.0	92.4	1.16	4.4	93.1	1.11	5.2	99.3	1.41	4.7
A. 1 letter	14	76.2	2.01	0.9				79.5	1.61	0.9	78.3	1.21	0.6
2 letters	7	97.0	0.88	7.3				95.1	0.83	4.6	107.8	0.93	3.9
3 "	6	144.2	1.64	5.8				139.3	2.05	8.0	166.9	1.76	3.7
4 "	6	167.3	2.13	6.9				169.2	2.42	5.6	182.1	3.12	6.7
Average	8	121.2	1.64	5.2				120.8	1.73	4.9	133.8	1.76	3.7
IV. 2 letters	10	107.7	1.92	2.5	103.0	0.96	2.8	110.1	1.27	3.4	118.6	1.32	2.9

The maximum ability is found at noon, the minimum at the extreme periods. It being winter, the tests at the latter times were often performed under artificial light, which may account for some of the difference. The omissions seem to vary inversely as the time, which fact would also decrease the differences between periods, as to their total efficiency. Subject A does comparatively better in the morning and decidedly worst at night.

Group B marked out two letters simultaneously and then a second combination of two on another blank, under a constant time-limit of 90 seconds for each period. The results appear in the next table, in terms of the average number of letters undone and omitted.

TABLE XVII. DISCRIMINATION OF LETTERS—LETTER BLANK.

Subject.	No. of Blanks.	9:00 A.M.				12:00 M.				4:00 P.M.			
		Undone.	P.E.	Omis.	P.E.	Undone.	P.E.	Omis.	P.E.	Undone.	P.E.	Omis.	P.E.
B	32	21.2	1.14	12.4	0.72	26.1	0.98	11.1	0.97	28.2	1.71	12.3	0.99

This shows a gradual increase of inefficiency from 9 A.M. on. The difference here may be due to sex, as subject A also shows a much worse night rate in this than in most of her tests. This increase was in spite of practise effect.

In a similar test, but using a book, subject I. marked out the e's on a page; then, in another series, the a's. The first period and the last two were subject to slight interruption, but the others to more.

TABLE XVIII. DISCRIMINATION OF LETTERS—BOOK PAGES.

Subj.	Letter.	No. of Days.	7:00 A.M. Time.	P.E.	Omis.	10:00 Time.	P.E.	Omis.	12:00–1:00 P.M Time.	P.E.	Omis.	4:00 Time.	P.E.	Omis.
I.	e	12	27.5	.41	.73	26.2	.40	.99	27.2	.23	1.27	25.6	.19	1.01
I.	a	17	28.5	.32	.37	26.6	.29	.35	27.1	.37	.41	26.7	.34	.60
Average		15	28.0	.36	.55	26.4	.35	.67	26.1	.30	.84	26.2	.26	.80

Subj.	Letter.	No. of Days.	7:00 P.M. Time.	P.E.	Omis.	10:00 Time.	P.E.	Omis.	12:00 M. Time.	P.E.	Omis.
I.	e	12	26.0	.20	.74	28.7	.56	1.12	—	—	—
I.	a	17	26.5	.35	.45	29.8	.37	.21	30.0	.23	.73
Average		15	26.3	.28	.59	29.2	.46	.66	30.0	.23	.73

No correction was made in 'time' for the varying number of e's to a page, as the same function is exercised in their absence as in their presence, but a slight allowance was made in 'omissions.' The order of abilities is about that found by the previous test, and the inverse relation of rate and accuracy is again hinted at.

Among the Exposition tests was one involving mainly judgments of shape and size, and a motor element. In a board, a foot square, were cut nine shallow holes of various sizes and shapes and in an irregular order. These shapes were partly in pairs, the members of which more or less closely resembled each other—in order to render their discrimination the more difficult. Blocks, shaped like the holes and supplied with handles, were to be inserted by the subject at the maximum speed possible and with the minimum error. The following average record was made by 60 Filipinos in the morning and 40 in the afternoon: A.M., time, 25.0 seconds, mistakes, 1.00; P.M., time, 25.5, and mistakes, 0.76. This is but a chance difference, if both ways of scoring be taken into account.

3. *Association*

Reaction-time, naming colors, and word associations will be considered in this connection. All involve discriminative and motor elements in varying degrees.

The experiments in reaction-time are limited in number. In simple reactions to a sound-stimulus, two subjects were tested with the Hipp chronoscope three times daily for four days, five reactions with each hand. In controlled reactions, two subjects were tested

for seven days, reacting to colors exposed by an electrical drop-screen in about three-thousandths of a second. The combinations of colors in a first series of experiments were standard red and green, red and orange; in a second series, red and the same red mixed with 50 per cent. of orange (R–O), then red and red with 25 per cent. orange (O–R).[1] The results of both forms of tests are in Table XIX.

TABLE XIX. REACTION-TIME AND TIME OF DAY.

Subject.	No. of Reactions.	9:00 A.M.				12:30 P.M.				5:00 P.M.			
		Time.	P.E.	Time.	P.E.	Time.	P.E.	Time.	P.E.	Time.	P.E.	Time.	P.E.
Simple reaction.		Right.		Left.		Right.		Left.		Right.		Left.	
I.	20	162	2.88	161	2.99	152	2.52	149	2.01	152	2.93	150	2.71
VII.	20	142	3.87	133	2.74	132	3.21	118	3.32	129	3.16	124	3.37
Controlled reaction.		R. & G.		R. & O.		R. & G.		R. & O.		R. & G.		R. & O.	
I.	208	255	1.51	281	1.56	244	1.62	278	1.56	253	1.62	283	1.38
III.	208	247	1.51	272	1.27	246	1.16	264	1.46	244	1.11	268	1.38
Controlled reaction.		R.&R-O.		R. & O-R.		R. & R-O.		R. & O-R.		R. & R-O.		R. & O-R.	
I.	156	265	1.45	274	1.26	265	1.39	276	1.52	266	1.39	280	1.26
III.	156	279	1.20	285	1.13	271	1.00	278	1.13	273	1.39	281	1.44

The superiority of the later two periods is apparent, and it should additionally be said that on two of the days it was so cloudy (January) that electric lights had to be used a short part of the last period. Possibly the motor element here has much influence in shaping the curve.

Ostanikow and Grau[2] measured four adults with the Hipp instrument—themselves, a servant (18 years) and a peasant (65). The periods were 9 A.M., 1, 4 and 7 P.M. They found the simple reaction-time shortest in early morning and the complex in early evening. Divergent results would be expected from so heterogeneous an age group.

Work done by Cattell and by Ellis and Shipe in connection with fatigue investigations, will be referred to later (see p. 82).

For the test in naming colors, ten one-cm. squares of each of ten different colors were pasted at intervals of one cm. on white cardboard, in irregular order. The subjects named these aloud as rapidly as possible, taking the time with a stop-watch. By holding the card

[1] This is also part of an investigation by Dr. V. A. C. Henmon, Columbia University.

[2] Bechterew, 'Ueber die Geschwindigkeitsveränderungen, etc.,' *Neur. Centralblatt.*, **12**, 9 Bd. 1893.

in different positions, the colors were presented in four different orders; and the experiment was so arranged that the same order was not presented in any two consecutive tests, though each order was used during a whole series an equal number of times for each period of the day. In the results, the first two days' records were omitted in allowance for practise.

TABLE XX. NAMING 100 COLORS.

Subject.	No. Named.	7–9 A M. Time.	P. E.	12–2 P.M. Time.	P. E.	4–6 P.M. Time.	P. E.	9–11 P.M. Time.	P. E.
I.	1,000	61.8	0.76	56.0	0.62	55.2	0.48	59.2	0.51
II.	1,000	68.8	1.10	62.1	0.76	63.1	0.67	67.3	1.22
V.	1,000	59.1	1.30	50.9	0.74	51.6	0.73	55.3	0.44
A	1,000	60.1	0.91	—	—	57.1	0.97	57.8	1.15

Here again the motor element may somewhat account for the obvious similarity to the diurnal curve already found for speed of movement.

In a lengthy list of tests given to Columbia students in their entering and final years, this one shows in the results a decided improvement to have occurred in the interval. This may be correlated with the intellectual development which has presumably taken place, but may on the other hand be correlated with the physical growth that has intervened. This test is not so simple as it seems. Among the perceptional, associational, expressional and other factors, one can not say how the time should be distributed, and yet just such knowledge as this in all our tests is required to properly relate the results obtained. The progress made in this refined work of correlating different functions with reference to their common or dissimilar elements will largely determine the value of the experimental psychology of coming years, from both the scientific and the pedagogical points of view.

In 'simple' word associations, at each period a list was used of 16 words (4 nouns, 4 adjectives, 4 verbs, 4 adverbs and prepositions), selected at random but arranged in a definite order. After each word was to be written the first one occurring to the mind after seeing it. Time was taken as in the other tests. The lowest section of Table XXI. gives results.

For controlled word associations, 420 words were selected, as nearly equal in difficulty as possible. From these, random lists of ten words each[1] were made up and these given to the subjects. It was hoped by a random arrangement to obviate differences of diffi-

[1] As 'supple, terse, aroused, insipid, ulterior, negligent, fitful, courage, profuse, stately.'

culty in the words. A word of opposite meaning was to be written after each one on the list. Words were chosen whose opposites could not be (easily) formed by annexation of prefixes or suffixes of negation, or by omission of the same. Of course it was impossible to avoid this entirely, though the subjects were also instructed not to make use of such opposites. Those taking the test thus are reported in the first section of Table XXI. The middle section gives the resulting figures when A and I. used two of the lists at a period, the rate for each list being shown in the case of A.

TABLE XXI. WORD ASSOCIATIONS—SIMPLE AND CONTROLLED.

Subject.	No. of Words.	7–9 A.M. Time.	P.E.	Mis.	12–2 P.M. Time.	P.E.	Mis.	4–6 P.M. Time.	P.E.	Mis.	9–11 P.M. Time.	P.E.	Mis.
					Controlled — 10 Opposites.								
I.	100	69.7	2.72	0.5	60.1	1.23	0.4	59.3	2.46	0.4	70.3	2.32	0.3
II.	100	50.6	1.72	0.1	43.6	1.71	0.1	46.0	1.76	0.0	45.1	2.36	0.1
III.	100	48.4	1.27	0.1	41.4	0.94	0.2	44.0	1.36	0.3	45.0	1.68	0.1
IV.	100	76.0	2.74	0.6	74.8	2.83	1.1	70.7	2.95	0.8	71.2	2.30	0.4
V.	100	54.2	2.23	1.9	46.6	1.64	1.9	48.2	1.19	1.4	45.0	0.96	0.5
Average	100	59.8	2.14	0.6	53.5	1.67	0.7	53.6	1.94	0.6	55.5	1.92	0.5
A.	140	63.8	3.01	0.1				57.2	2.07	0.1	61.2	2.86	0.2
					Controlled — 20 Opposites.								
I. per 10	100	56.2	2.12	0.2	55.8	1.74	0.6	55.5	1.97	1.0	57.5	1.86	0.5
A. 1st 10	70	46.0	2.91	0.2				38.7	1.91	0.1	47.7	2.33	0.1
A. 2d 10	70	50.4	3.00	0.3				39.4	2.13	0.1	45.0	2.97	0.2
					Simple — 16 Words.								
I.	160	51.8	0.51		51.4	0.58		49.9	0.50		50.2	0.59	
A.	162	51.0	0.83					53.8	0.92		53.9	1.10	

This table makes the first period of the day the worst, while noon seems the best. The P.E.'s show that a longer series is needed, but it would be exceedingly difficult to find in the 150,000 usable words of the English language 100 more with the requisite qualifications for this test.

Fifty of these words were given to the group of young women, 240 seconds being allowed in which to write the opposites. To bring this more into line with the others, the number of words *undone* was used as the basis of the estimates. The results were: 9 A.M., undone 19.1 and mistakes 3.5; 12 M., 18.3 and 2.3; 4 P.M., 17.0 and 3.4. The differences here are not decisive: the P.E.'s are large, because the subjects hunted easy words instead of taking them seriatim. The morning figures are probably affected by newness of test.

This test seems of doubtful utility for the present purpose, if it is admitted that writing ability varies for time of day. Subjects

I., IV., V., A and B took the rate test for writing and the general order of each in the two cases is notably similar (see Table IV., p. 18). The quicker the real association-time of the individual, the greater would such vitiation be. Being designed for the use of students, the words picked were of two and three syllables, with some hard monosyllabics needed to fill out the desired number. This meant long opposites, and much time devoted to the merely mechanical act of writing. Also, while 100 words at each period give fair chance for equal distribution of hard ones, the P.E. in this test will always remain large on account of them. The inverse relation of speed and mistakes, seen in the results, again shows the need of a coefficient which would allow the transmuting of the one into terms of the other, and it is not altogether improbable that such a figure could be found if careful search were made.

4. *Memory*

This was tested in several ways. Subject I. selected 1,200 German words, with which he was unfamiliar, and arranged them in random lists of ten each, with their corresponding English meanings. The time consumed in memorizing one of these lists, maintaining correctness of meanings and relative positions of all words, was secured at ten periods, for twelve days. The lists were used a full year after their preparation. The external conditions during the progress of this test were excellent, being practically unvaried from day to day. The entire twelve days were devoted to experimentation, from 7:30 A.M. till 11 P.M., excepting for meals, 8 to 8:30 A.M., 12 to 1:30 P.M., 6:30 to 7:30 P.M. The same thing was done at the same hour each day. This program was adhered to without change and without interruptions, so that none but constant causes influenced any of the trials. But the increasing monotony of the task may have somewhat affected the later periods of the last few days. The results, in Table XXII., are in terms of the average number of seconds required to learn each list fully.

TABLE XXII. MEMORY—10 GERMAN WORDS AND THEIR MEANINGS.

No. of Words	7 A.M. Time.	P.E.	8:30 Time.	P.E.	10:00 Time.	P.E.	11:30 Time.	P.E.	1:30 P.M Time.	P.E.	3:00 Time	P.E.
120	371	10.26	390	14.34	386	10.09	434	16.89	475	12.11	460	11.21

No. of Words.	4:30 Time.	P.E.	6:00 Time.	P.E.	7:30 Time.	P.E.	9:00 Time.	P.E.	10:30 Time.	P.E
120	445	15.19	431	15.02	444	16.72	544	15.13	613	17.33

This table shows some clear variations. The morning is by far the best; a slump occurs between 1 P.M. and 3:30 P.M.; then a level

period till 8 P.M.; after which there is a decided drop. The normal curve of the author's subjective feelings follows a like course, save as to the degree of the night drop. The other tests of memory on myself should not have the same weight as these figures, though, as a matter of fact, they corroborate them.

This subject used also lists of eight single numerals for visual memory, exposing at a uniform rate the successive figures on cards. Three of these were used each period for thirty days. The first period and the last two were liable to little interruption; the others to more. Only the average number of mistakes is shown in the following results:

7 A.M., 0.8; 10 A.M., 1.9; 1 P.M., 1.8; 4 P.M., 1.8; 7 P.M., 1.5; 10 P.M., 1.2.

The middle three can not be compared with the others, for the reason already stated, but show no differences among themselves. The first period is most probably the best.

Subjects III., IV., V. and VI. pursued the same method with lists of nine figures. They counted their own mistakes, cases of incorrect order being called erroneous as well as wrong figures. The P.E.'s are calculated from the whole series, though some practise effect is apparent—but two days were omitted for III. The results are the first in Table XXIII.

TABLE XXIII. MEMORY—9 FIGURES AND 16 WORDS.

FIGURES. Subject.	No. of Lists.	7–9 A.M. Misses.	P.E.	12–2 P.M. Misses.	P.E.	5–7 P.M. Misses.	P.E.	9–11 P.M. Misses.	P.E.
III.	30	1.5	0.38	1.2	0.39	1.1	0.26	1.8	0.27
IV.	30	3.1	0.53	2.6	0.32	3.1	0.33	3.4	0.34
V.	36	5.8	0.37	4.0	0.42	3.3	0.54	4.7	0.47
VI.	30	3.3	0.40	3.1	0.34	2.0	0.48	3.9	0.39
Average.......	32	3.4	0.42	2.7	0.37	2.4	0.40	3.4	0.37
WORDS.									
I.	48	8.1	0.58	10.4	1.71	9.4	0.82	9.8	0.91
II.	48	4.0	0.23	9.0	0.44	6.1	1.10	7.2	0.55
A	48	6.2	0.28			6.1	0.29	7.1	0.31
FIGURES.									
Subj. A Visual......	24	1.5	0.18			2.5	0.39	3.1	0.76
Subj. A Auditory...	42	1.3	0.31			0.7	0.18	2.2	0.52
Subj. A Vis.-Aud...	16	1.0	0.32			1.3	0.28	1.3	0.35
Average.......	27	1.3	0.27			1.5	0.28	2.2	0.54

Subjects I., II. and A were tested in visual memory with words —four groups of four words each, every period. The words of a group were more or less logically connected, as they were cut from newspaper sentences. These partial clauses had been pasted on

separate strips of cardboard, for ready exposure, as in the other memory test. Hence each effort of the memory was an attempt to recall sixteen words thus arranged and handled. The results in the middle section of Table XXIII. are in terms of the mistakes.

For subject A, results from the following tests are then shown: (1) visual memory, with lists of nine figures; (2) auditory, similar lists being read aloud to the subject; (3) auditory-visual, the figures being both heard and seen simultaneously.

The first group, consisting of the four subjects III., IV., V., VI., as a whole conforms the most closely to the type of efficiency reaching a significant maximum in the midday periods. But in the other subjects the tendency is strong to a morning maximum and to a noon minimum, in the case of the males, and a night minimum for the females.

The auditory memory tests with numerals were given to the Teachers College female students, six lists being used at each period for one day; and to subject VII., three lists being used at each period for four days. Results:

	B.		VII.	
	Mis.	P. E.	Mis.	P. E.
9 A.M.,	9.0	0.7	4.5	0.6
12 M.,	6.9	0.6	4.5	0.8
4 P.M.,	7.0	0.5	4.8	0.5

Newness of the test at the first period and practise effect at the others tend to make these differences problematical in the case of the young women, while they seem chance differences in case of subject VII.

Larguier[1] memorized passages of ten sentences from Racine and measured results in number of seconds required to do the learning, obtaining, before coffee, 316 (av. of 16 days); before lunch, 349 (8 days); after lunch, 341 (7 days); before dinner, 345 (9 days); after dinner, 280 (5 days). In reproduction of the passages 24 hours later, he found the best results after dinner and the worst at the first period. Besides being the record of only one subject these results fall under the criticism explained early in this paper (p. 2), in that, as seen from the differing figures in parentheses, valid results were expected, in short series, from experiments where every period of the maximum number of days reported had not been duly used.[2]

[1] 'Note sur les Variations de la Mémoire au Cours de la Journée,' *L'Année Psych.*, 8: 205–213. 1901.

[2] This is strikingly shown in another series, of ostensibly 14 days' length, testing the effect of alcohol on memory, where only rarely do two experiments seem to have been taken the same day before and after lunch.

Thus no account was taken of the inevitable difference of efficiency between one day and another.

M. C. Schuytens, in an article soon to be mentioned, finds memory in school children, in class tests, to be dependent on whether their first trials are made in the morning or in the afternoon. In other words, it is entirely a matter of interest with them; they lose interest after the first trial.

The total outcome as to memory must be considered a negation of the existence of a simple diurnal memory curve, though this point will be touched again in the subsequent discussion of fatigue.

II. The More Complex Mental Activities

1. *Arithmetic*

This has long been a favorite test, supposedly of general mental efficiency. This special preference has been due largely to the traditional conception that no other school branch is so difficult for the ordinary student to master, that it is more purely logical in nature, and partly to the experimental evidence furnished by certain investigators of the question of school fatigue.

It is scarcely allowable at the present day to accept an arithmetical test as a measure of general mental efficiency. The mere fact of difficulty does not prove it to be such a measure; rather must the causes of this difficulty first be determined by means of refined empirical analysis, which can not be attempted here. An arithmetical test does no doubt call for the exercise of various important mental powers, such as attention, discrimination, memory, etc.; but though these generic terms are convenient, their application to concrete cases requires more particularization and qualification, as already remarked. The attention, discrimination and memory involved in an example in multiplication are not quite the same processes as have been studied in the preceding tests. For our present purpose, the arithmetical tests are to be regarded simply as measures of efficiency in a rather complex and very practical sort of mental work.

1. *Addition.*—Subject I., for 28 days at the periods shown in the lowest part of Table XXIV., added six columns (25 figures each) as rapidly as possible, timing with a stop-watch. The average time in seconds is shown. The first six subjects used ten columns (15 figures each): A used six columns. Some correction was made for practise in the first five days.

TABLE XXIV. ADDITION—COLUMNS OF 15 FIGURES.

Subject.	Total No. of Columns.	7–9 A.M.			12–2 P.M.			5–7 P.M.			9–11 P.M.		
		Time.	P.E.	Mis.	Time.	P.E.	Mis.	Time.	P.E.	Mis.	Time.	P.E.	Mis.
I.	140	99.4	1.00	1.2	91.9	0.91	0.6	92.6	0.86	1.4	97.0	0.89	0.9
II.	120	110.2	1.11	0.8	99.1	1.44	0.7	106.9	1.32	0.9	109.2	1.67	1.1
III.	120	89.5	1.28	1.0	87.3	1.13	0.7	86.0	0.90	0.7	85.3	0.90	1.5
IV.	100	66.3	0.55	0.6	64.7	0.78	0.8	63.6	0.78	0.6	69.2	1.52	0.6
V.	120	105.2	0.99	1.3	90.8	0.81	0.6	99.2	0.88	1.0	98.8	0.69	1.2
VI.	100	122.3	1.78	1.1	119.4	1.81	1.4	123.0	1.58	1.0	116.9	1.79	1.2
Average.	117	98.8	1.11	1.0	92.2	1.15	0.6	95.2	1.06	0.9	96.1	1.24	1.08
A	84	112.3	2.4	1.2	—	—	—	106.7	2.1	1.1	107.6	2.5	1.4

Cols. of 25 Figs.	7 A.M.	10 A.M.	1 P.M.	4 P.M.	7 P.M.	10 P.M.
I. 150	29.6 0.22 1.1	28.4 0.28 1.0	29.2 0.28 1.0	28.5 0.29 0.8	28.0 0.24 1.0	31.0 0.29 1.0

The fact found here is a higher efficiency at the noon period and a lower efficiency in the morning than at the other periods, with the usual individual divergencies rather minimized. Accuracy pursues the same course as speed, which is noteworthy when compared with its tendency in the other tests. In the lower case of subject I., the 10 A.M., 1 and 4 P.M. periods were affected by occasional interruption.

Subject VII., in an uncompleted series of four days, took this test at 9 A.M., 12 M. and 4 P.M., and made this record:

232 (P.E., 3.2); 215 (2.1); 227 (2.9).

Each member of group B was given 24 of these 15-figure lists, and 240 seconds in which to add them. Their results are expressed in terms of the average number of *columns done* and the P.E.:

15 (1.4); 14 (1.3); 15 (1.3).

This is a chance order. Here, as in memory, the first trial is at a disadvantage because of newness of the test, while the others are more favored by practise.

2. *Multiplication.*—In mental multiplication, subject I. for twelve days, under the very favorable conditions described for the German words memory test, used two-place numbers after excluding 0, 1, 2 and 5—though 5 was used in hard combinations. Being a poor visualizer, the author found this to be a sufficiently difficult test. At each period, three pairs (on some days four) of such numbers were multiplied, and the time taken as before.

The first two are the periods of highest ability; from 1:30 P.M. to 3 P.M., at 6 P.M. and again at 10:30 P.M. occur the points of greatest inefficiency. This very closely follows the diurnal curve of subjective feeling alluded to above. It is nearer that for memory than for addition, though really comparable figures are not at hand.

The order shown is heightened in validity when the mistakes are also considered; there is no inverse relation here.

TABLE XXV. MENTAL MULTIPLICATION—NUMBERS OF 2 FIGURES.

Subj.	No.	7:00 A.M.			8:30 A.M.			10:00 A.M.			11:30 A.M.		
		Time.	P.E.	Mis.	Time.	P.E.	Mis.	Time.	P.E.	Mis.	Time.	P.E.	Mis.
I.	40	37.6	2.4	.50	34.7	1.6	.50	39.7	2.5	.63	41.8	1.7	.50

Subj.	No.	1:30 P.M.			3:00 P.M.			4:30 P.M.			6:00 P.M.		
		Time.	P.E.	Mis.	Time.	P.E.	Mis.	Time.	P.E.	Mis.	Time.	P.E.	Mis.
I.	40	4.80	2.6	.70	45.3	2.6	.83	41.0	1.8	.60	47.1	2.4	.71

Subj.	No.	7:30 P.M.			9:00 P.M.			10:30 P.M.		
		Time.	P.E.	Mis.	Time.	P.E.	Mis.	Time.	P.E.	Mis.
I.	40	39.8	1.9	.53	41.7	1.8	.63	47.0	2.6	.73

In the following section (p. 75), reference will be made to work in addition done by Roemer, who finds the first of four morning periods the best; and by Thorndike (p. 85), who also found the ability slightly the best then. The latter, in mental multiplication, found in a very short series the night period a little better for adults; while in written multiplication a very extensive test of school children (750) favored the morning.

2. *Translating French; Scoring Death Records*

Subject I., under the excellent conditions of all-day experimentation described above, translated French at seven different periods of an hour each, every day for twelve days. It would seem at first thought that translation by mere reading is a better test than that by writing, since the latter involves a motor element. However, the former is subject to a subtler and no less vitiating complication. All that one aims to do by the reading method is to get the meaning, and that usually amounts to merely *sensing* the meaning. This process is so indefinite and the quality of the results so indifferently estimated as to make unreliable all objective measurement based on the number of sentences thus subjectively rendered. That is, the work at those periods of the day when feelings of fatigue are most pronounced would unconsciously be slurred over, while at those times when one is most conscientiously sensitive to his duty it would be relatively slow. The net result would be a lessening of the diurnal differences. No such fast-and-loose interplay can well be indulged in when the product is in sight, and for this reason the other method was selected. Scientifically unsatisfactory, it yet gives an idea of what might be expected in the practical matter of written translation.

TABLE XXVI. FRENCH TRANSLATION—SENTENCES WRITTEN PER HOUR.

Subject.	9:00–10:00 A.M. No.	P.E.	10:30–11:30 No.	P.E.	2:00–3:00 P.M. No.	P.E.	3:30–4:30 No.	P.E.	5:00–6:00 No.	P.E.	8:00–9:00 No.	P.E.	9:30–11:30 No.	P.E.
I	50	0.88	51	1.03	54	1.17	55	0.77	54	1.12	56	1.02	57	0.44

The morning work is slowest, the afternoon medium, and the night swiftest. In accounting for the higher night efficiency, the following factors seem to figure in the result and to be of weight in the order named: (1) quicker motor functioning; (2) practise effect; (3) habit; (4) end-glow.

In examining the 36,000 death records, reported earlier in the paper, ten days were consumed by subject I. at the New York City Health Department offices. Work was begun promptly at 9 A.M. and continued without interruption till 12:45 P.M.; beginning at 1:15 P.M. there was no break till 4 P.M., when the office closed. During this time, tab was kept on the exact number of records handled every fifteen minutes, and the average scores obtained are in the following table. The fourth and fifth results are estimated from work of three quarters of an hour in length.

TABLE XXVII. DEATH RECORDS.
AVERAGE NUMBER EXAMINED EACH FOURTH OF AN HOUR.

Subject.	No. of Days.	9–10 A.M. No.	P.E.	10–11 A.M. No.	P.E.	11–12 A.M. No.	P.E.	12–1 P.M. No.	P.E.	1–2 P.M. No.	P.E.	2–3 P.M. No.	P.E.	3–4 P.M. No.	P.E.
I.	10	138.6	1.06	135.0	1.34	133.9	1.23	131.4	2.39	133.1	2.11	130.1	2.03	142.1	1.79

There is a decided falling off after the first hour which continues till noon intermission; then a slight recovery, followed by the lowest point reached, which is itself succeeded by the highest point. This curve can not be said to follow, throughout its whole course, that of any other measured activity of this subject. This is not odd, as the operation involved was a very complex one. Five things had to be noted in different parts of the death certificate—cause, time and season of death, age and sex. While being located properly on the score sheets—a process again involving much discrimination—they had to be carried in mind or else a second look was required. Judgment was also required in the work; but memory and movement were apparently the most telling elements in determining the curve. Good memory favored a strong beginning in the morning and good motor rate a strong ending in the afternoon, while the period from 1 P.M till 3 P.M. was specially unfavorable to both. The impulse to finish a certain number before four o'clock, if possible, was always too great to be resisted, even when note was taken of the accelerated

rate and it was felt that the results were being unduly affected. Yet it must be recalled that every effort was made throughout the day to do the utmost possible consistent with accuracy. End-glow has often established its claim to recognition, but no special practical use of it suggests itself.

3. *School Examinations and School Marks*

Rice[1] conducted some very extensive tests in spelling and arithmetic, to ascertain the relative values of different methods of administration and teaching, and other points of educational import. The arithmetical investigation was carried on with 6,000 children, of eighteen schools, in seven cities, and consisted in giving certain examples to be worked, the total outcome of which was then scored up in several ways—(*a*) per cent. correctly done; (*b*) per cent. with principle correct; (*c*) average number of mechanical errors made. About half of the tests were given in the morning and half in the afternoon.

As far as Rice's work touches the present problem, his ideas are fully set forth in the following quotation, it being understood that the table referred to by him shows only incidentally the times of day when the schools were examined, and does not collate the results quantitatively from this point of view, which is investigated only in the desultory fashion betokened by his remarks:

> The idea is generally accepted that an examination in arithmetic given in the morning will show much more favorable results than one given in the afternoon, and it, therefore, might be supposed that the schools that did best had been examined in the morning, and *vice versa*. When the table was examined from this standpoint the indications appeared to favor the theory; but the quantitative aspect has certainly been exaggerated. Looking at the facts we find that . . . the first three schools of city I. were examined in the morning and did well. The fourth of that city was examined in the afternoon and also did well. The point of particular interest is the fact that the school by being examined in the afternoon did not lose its classification (rank). . . . Thus while there seems to be some advantage in an examination in the morning, the figures appear to leave no doubt that a school that can do well in the morning can also do well in the afternoon, and conversely. . . . I have heard it stated that the difference between a morning and an afternoon examination will probably reach 20 per cent.

His table is extensive, showing results separately for each school grade examined. By averaging together all grades of each school, the figures of Table XXVIII. were obtained as measures of the different schools as wholes. Eight were examined in the morning and ten in the afternoon; to get equality, the records of schools II.

[1] 'Educational Research,' *Forum*, **34**: 281–297. 1902.

and V., falling practically at the median for all the afternoon schools, were omitted.

TABLE XXVIII. A TEST IN ARITHMETIC—REVISION AFTER RICE.

City.	School.	Morning.			Afternoon.		
		Work Correct.	Principle Correct.	Mechanical Errors.	Work Correct.	Principle Correct.	Mechanical Errors.
III.	1	80.0	83.1	3.7			
I.	1	76.6	80.3	4.6			
I.	2	69.3	75.1	7.7			
I.	3	67.8	72.2	6.1			
I.	4				64.3	70.3	8.5
III.	2				54.4	58.9	7.4
IV.	1	55.1	58.4	5.6			
IV.	2				53.9	58.8	8.3
IV.	3	51.5	57.6	10.5			
IV.	4				42.8	48.2	11.2
VI.	1	39.0	42.9	9.0			
VI.	2				36.5	43.6	16.2
VI.	3				36.0	42.5	15.2
VII.	1	40.5	45.9	11.7			
VII.	2				36.5	40.6	10.1
VII.	3				25.3	31.5	19.6
Averages of the 8 Schools' Averages.		60.0	64.4	7.4	43.7	49.3	12.1

A glance at this table shows a decided superiority of the morning over the afternoon schools, the latter doing only about 70 per cent. as well as the former, taking all three modes of scoring into consideration. This would certainly have been observed by Dr. Rice if he had thought it worth while to make other than a casual comparison. Several of his quoted statements seem unhappily framed, in the light of this revised tabulation. It may be urged against this revision that the best cities were tested mostly in the morning and the poorest mostly in the afternoon. Of course there is no way of knowing offhand whether this is true or not, but it will be found by examination of the table that the percentage of difference still remains considerable when only schools of the same city are compared with each other. When the extensiveness of the experiments and the decisiveness of the results are both considered, such figures have no small importance for the view that children reach their maximal period of customary efficiency earlier than adults.

The writer attempted to get school marks of different classes in the same branch, under the same teacher, but meeting at different times of day, in the New York City High Schools. Only one school was found in which the conditions were favorable. In that about fifteen teachers had from two to four classes of the kind required,

and to each of these teachers was given written information as to the problem and its pedagogical bearing, together with the nature of the data desired, and a blank form upon which the marks could be readily copied. It would have taken a live teacher about fifteen minutes to transcribe the marks of four ordinary classes, whereas it took the author a day—after getting the school located—to do his part: as result, one teacher responded with four classes.

Two first-year morning classes in botany, 23 pupils each, averaged 62 and 67, while two in the afternoon, of 24 and 25 pupils, averaged 61 and 62. This whole case is introduced to show the need of a more general and extensive sympathy with scientific efforts. While *only* 78 per cent. of the manufacturers and 80 per cent. of the physical directors and athletes failed to make a response of any sort, 92 per cent. of the educating class itself took this frigid attitude, and that, too, when less was individually required. The loss to science is not great in regard to the school marks, as the bases of grading, with different teachers, are quite variable factors.

4. *Students' and Authors' Preferred Hours for Work*

The work of O'Shea's,[1] incidentally mentioned above, is largely based on the answers received to a questionnaire sent to the students of the University of Wisconsin. Two of the questions were—During what hours of the day are you at your best? and, When are you dullest? The total number of answers received is not stated, but the number treated is 316. To this topic, in the text, he devotes little more than a page, from which the following quotations are made: "Practically all those who reported testified that their minds worked best in the forenoon, eighteen reported being best in the afternoon, while two found that they could accomplish more at five o'clock in the morning than at any other hour. The best hours ranged from 7 to 12 in the forenoon while the choicest period of the day is from 9 to 11." It is unfortunate that the second question was entirely ignored, though we are just as much interested in knowing its answer. To thus omit half a fact seems unscientific.

Quoting again (p. 195), "There can be little doubt that for most people the morning hours are most profitable to be devoted to diligent, concentrated study. The afternoon hours can be employed to greater advantage in duties demanding less energizing of the will; while in an ideal program the evening hours will be spent almost wholly in relaxation. . . . 2 students reported not studying beyond 8 (at night); 44 worked until 9; 187 until 10; 70 until 11; 9 until 12; and 1 until 1. . . . Forty of those who studied very

[1] 'Aspects of Mental Economy,' *Bul. of Univ. of Wis.*, **2**: 34–198. 1901.

late into the night testify that the knowledge they acquired stayed with them; 58 said that in the morning it, like the Arab, had folded its tent and silently slipped away.''

This oriental allusion recalls what Dr. J. M. Scott, Professor of Greek in Northwestern University, recently[1] said so directly to the contrary in addressing his class on 'burning the midnight oil'. ''In olden days,'' he stated, ''the Persians congregated at daybreak to pursue their studies; but nowadays the great scholars pore over their books at night. In the morning one's eyes are not clear, his head still is numb from sleep, and he is in no condition for mental work. Because of lack of illuminating facilities the ancients were obliged to study in the early morning. Although I would not urge any of you to refrain from rising early, I would advise you to do your studying at night.''

It is a question for serious consideration whether an occasional sacrifice to overstudy should not be made rather than that such an arbitrary rule of ten o'clock retirement should be imposed as exists at most of our women's colleges. When one gets 'into the swing' he can often accomplish more in six or eight consecutive hours of night work than in double that number of hours of day work done in bits, as it often is. Whenever a person can work with the least expenditure of energy is the proper time for him to do so.[2] There seems no more reason in trying to fit all types of students to one sort of study-hour jacket than in attempting to place one kind of instruction-plan coat upon all kinds of developing individualities. Authors have learned this general fact by experience and take advantage of it in their work, if the following account of them is typical, as it seems to be.

Hundreds of biographies[3] were scanned for the occasional words treating the matter of authors' preferred hours for composition. Some 160, odd, cases were found, definite enough for accurate use, and of these 160, even, of the best were selected for reporting here. These distributed themselves diurnally in this manner: *morning* composers (6 A.M. to 2 P.M.), 55, or 34 per cent.; *afternoon* (2 to 7 P.M.), 2, or 1 per cent.; *night* (7 to 12 P.M.), 17, or 12 per cent.; *after midnight* (12 to 6 A.M.), 9, or 6 per cent.; *morning and afternoon* (6 A.M. to 7 P.M.), 27, or 17 per cent.; *morning and night* (6

[1] March 24, 1905.

[2] See Hamerton's *Intellectual Life,* pp. 380–400, for instructive treatment of this question.

[3] About 100 volumes were examined in this search. The two of most value were Dr. Hugo Erichsen's *Methods of Authors,* 1894, and *Aspects of Authorship,* by F. Jacox, 1872.

A.M. to 2 P.M. and 7 to 12 P.M.), 6, or 4 per cent.; *afternoon and night* (2 to 12 P.M.), 4, or 3 per cent.; *whole day* (6 A.M. to 12 P.M.), 37, or 23 per cent. Some writers were included whose actual working hours were secured, but not their expressly preferred hours. Some, who were assigned to the first, fifth or last group, might almost as correctly have been put in the 'night' group, for one reason and another, and this would raise the percentage of the latter somewhat. Secondary preferences are shown in parentheses in the detailed list now to be given. The chief field of each one's activities is only partially indicated in most of the cases. The letter *F,* in parentheses, means 'female.' The lists are arranged alphabetically.

Morning: J. Addison (Eng. essayist), G. von Amyntor (Ger. novelist), L. A. Banks (Am. clergyman and author), V. Blüthgen (Ger. novelist—night), C. Brontë (Eng. novelist and poet—*F*), E. Brontë (Eng. novelist and poet—*F*), M. Cawein (Am. poet), T. Chalmers (Eng. theologian and journalist), G. M. Craik (Eng. novelist—*F*), C. Deslys (Fr. novelist), C. Dickens (Eng. novelist), J. Dryden (Eng. poet), R. W. Emerson (Am. philosopher and essayist—night), M. Eytinge (—— poet and novelist—*F*), K. Field (Am. novelist—*F*), K. Frenzel (Ger. journalist—night), O. F. Genischen (Ger. dramatist), E. Gibbon (Eng. historian), J. W. Goethe (Ger. poet), E. Gosse (Eng. poet and critic—night), E. E. Hale (Am. essayist), R. Hamerling (Austrian novelist), O. W. Holmes (Am. poet and humorist), W. D. Howells (Am. novelist), V. Hugo (Fr. novelist), L. Hunt (Eng. poet—night), W. Irving (Am. novelist), D. W. Jerrold (Eng. dramatist and journalist—night), I. Kant (Ger. philosopher), T. B. Macaulay (Eng. essayist), H. Martineau (Eng. novelist—*F*), (J.) B. Matthews (Am. dramatist and critic—night), J. Miller (Am. poet), J. Milton (Eng. poet—afternoon), A. Niemann (Ger. novelist), A. Pope (Eng. poet—day), L. de la Ramee (Eng. novelist—*F*), E. Richebourg (Fr. novelist), J. P. Richter (Ger. poet), L. de Sacher-Masoch (Fr. story writer—afternoon), J. Scherr (Swiss novelist and historian), Sir W. Scott (Eng. novelist), W. G. Simms (Am. poet—night), F. R. Stockton (Am. novelist), J. Taylor (Eng. poet and novelist—*F*), W. M. Thackeray (Eng. novelist), A. Thuriet (Fr. novelist), M. Thompson (Am. critic and essayist), E. Vely (Ger. novelist—*F*), P. Virgil (Latin poet), R. Waldmueller (Ger. novelist), D. Webster (Am. statesman), E. Wichert (Ger. novelist), C. M. Yonge (Eng. novelist—*F*), C. Kingsley (Eng. clergyman and novelist—night).

Afternoon: S. O. Jewett (Am. story writer—*F*), A. Traeger (Ger. poet).

Night: V. Alfieri (Italian dramatist), W. B. Blake (Eng. poet—after midnight), K. S. Bonner (Am. story writer and novelist—*F*), R. S. Cabanis (Ger. humorist—after midnight), Wm. Collins (Eng. poet), J. Fastenrath (Ger. and Span. poet), R. E. Francillon (Fr. novelist and journalist—afternoon), F. Friedrich (Ger. novelist), W. A. Hammond (Am. novelist—after midnight), T. Hardy (Eng. novelist—day), J. C. Harris (Am. humorist and journalist—day), H. Herberg (Ger. novelist), T. Hood (Eng. poet and humorist—day), S. Johnson (Eng. essayist and lexicographer—day), C. Lamb (Eng. poet—after midnight), M. J. Preston (Am. poet—*F*), S. Rogers (Eng. poet), P. K. Rossegger (Austrian novelist), R. B. Sheridan (Eng. dramatist), R. Southey (Eng. poet—day).

After midnight: H. de Balzac (Fr. novelist), Lord Byron (Eng. poet), S. T. Coleridge (Eng. poet), T. De Quincey (Eng. essayist), J. Fane (Eng. poet), Lord Jeffrey (Eng. poet), E. A. Poe (Am. poet and story writer), H. Rollet (Austrian poet—night), F. Schiller (Ger. poet—night).

Morning and afternoon: L. Anzengruber (Austrian story writer), R. Baumbach (Austrian poet), J. Burroughs (Am. naturalist), T. Carlyle (Scot. essayist and historian), J. Clarétie (Fr. novelist), M. D. Conway (Am. essayist), F. Dahn (Ger. historian and poet), G. M. Fenn (Eng. novelist), P. Galen (Ger. novelist—night), A. Glaser (Ger. novelist—night), R. von Gottschall (Ger. novelist and journalist), M. Greif (Ger. poet), L. Habicht (Ger. novelist), T. W. Higginson (Am. novelist and essayist), L. Larcom (Am. poet—*F*), H. Malot (Fr. novelist), T. Moore (Eng. poet), J. Nordmann (Ger. novelist and journalist), U. Prynne (Eng. controversialist), W. H. Riehl (Ger. novelist), E. P. Roe (Am. novelist—night), J. Stinde (Ger. satirist), C. Thaxter (Am. poet—*F*), J. T. Trowbridge (Am. novelist), J. G. Whittier (Am. poet), A. von Winterfeld (Ger. humorist), J. Wolffe (Ger. poet).

Morning and night: R. Burns (Scot. poet), O. Goldsmith (Eng. poet and novelist), N. Hawthorne (Am. novelist), Plato (Gr. philosopher), F. W. Robertson (Scot. clergyman and author), S. Smith (Eng. poet and critic).

Afternoon and night: T. Campbell (Scottish poet and novelist), W. Hazlitt (Eng. critic and essayist), J. Rousseau (Fr. philosopher and educator), A. Streckfuss (Ger. novelist).

Whole day: L. M. Alcott (Am. novelist—*F*), H. H. Bancroft (Am. historian) 'Venerable Bede' (Eng. author), E. Bulwer-Lytton (Eng. novelist and poet), W. Carleton (Am. poet), T. Carte (Eng. historian), Wilkie Collins (Eng. novelist), Delambre (Fr. philosopher), A. L. G. N. De Staël (Fr. novelist—*F*), G. Ebers (Ger.

novelist—night), J. Fiske (Am. historian and essayist), P. H. Hayne (Am. poet), J. Hogg (Scot. poet and biographer), J. Keats (Eng. poet), W. S. Landor (Eng. poet), S. Lanier (Am. poet and novelist), O. von Leixner (Ger. poet, historian and novelist—night), P. Lindau (Ger. novelist), H. W. Longfellow (Am. poet), Mazerai (Aus. historian), A. Meissner (Austrian novelist—night), J. L. Motley (Am. historian), J. Payn (Eng. novelist), F. Petrarch (Italian ecclesiast and poet), W. H. Prescott (Am. historian), B. W. Proctor (Eng. poet), F. Rabelais (Fr. educator and humorist), L. von Ranke (Ger. historian), J. W. Riley (Am. poet), W. Robertson (Eng. historian), P. B. Shelley (Eng. poet), K. Stelter (Ger. poet—night), H. B. Stowe (Am. novelist—*F*), H. D. Thoreau (Am. author), E. M. Vacano (Ital. author), J. Wilson (Scot. essayist, novelist and poet), W. Wordsworth (Eng. poet).

Numerically, morning stands easily in the lead among the different groups, and this precedence might be emphasized if those persons could be segregated from the fifth, sixth and eighth groups who were obliged by financial necessity, or social custom, to scatter their work over such extensive periods of the day.

But an accurate estimate of the night workers will show this general group a closer second to the former than appears at first sight. Again we must make allowance for those included in groups 6, 7 and 8 who would preferably work only at night if composition depended only on inclination. Fourteen, outside of the distinctively night groups, have indicated a night choice, and should likely be classed there, as they have for the most part stated that this period seemed the best for the 'creative' part of their labor, at least, or was preferred in early life. Psychologically, it may not be entirely true that imaginative work is more creative than certain other kinds, but it is usually so considered among the writers themselves.

If we take the 'internal evidence' of the groups themselves, it is possible to get a little added light on this matter of the best times for different sorts of composition. That is, if the poets and novelists are roughly designated as an *imaginative* class, and the historians, clergymen, essayists, critics, journalists, philosophers, etc., as a broader, *intellective* class, we shall find the former predominant in the morning and night groups and the latter in the day ones. Entire confidence can not be placed in this division, as the original assignment of 'fields of activity' to the various writers is not thoroughly exact, in that it is much too limited per individual. But certain special groups tend to confirm the conclusion. Thus, of thirteen historians mentioned, eleven occur in the all-day section; and of the

after-midnight workers *all* are of the imaginative type—if De Quincey's product is allowed to be prose-poetry, as it is often styled.

While the theory that night furnishes the best time for original composition is thus at least strongly suggested, it seems to the present writer lacking in ground to support such *extreme* views as have been advanced by some. De Quincey is authority for this statement of C. Lamb: "No true poem ever owed its birth to the sun's light. The mild internal light, that reveals the fine shapings of poetry, like fires on the domestic hearth, goes out in the sunshine. Milton's Morning Hymn in Paradise, we would hold a good wager, was penned at midnight, and Taylor's rich description of a sunrise smells decidedly of a taper." This view, besides being worded possibly for effect, is influenced by his own actual practise in regard to night work. Erichsen, alluded to above, is a whole-hearted convert to the theory, though no little could be cited against its unconditional adoption from his own book. He remarks that Lamb's tasks "courted the aid of evening, which by means of physical weariness produces a more luxurious state of repose than belongs to the labor hours of day. . . . They [the words 'physical weariness'] almost exactly define that unnatural condition of the body which on other grounds appears to be proper to the *unnatural* exertion of the mind." The extent to which he carries the latter idea may be gathered from a reference of his to Scott, in another connection. Scott had said of his own review of Ritson's Caledonian Annals that "no one who has not labored as I have done on imaginary topics can judge of the comfort afforded by walking on all fours, and being grave and dull." "There spoke the man," says Erichsen, "who habitually and without artificial help drew upon his imagination at the hours (in the morning) when instinct has told others that they should be employing, not their fancy, but their reason. So Scott compelled himself to do *unhealthy or abnormal* work without the congenial help of abnormal conditions."

Such ideas quite ignore the fact of individual differences—that many have accomplished as good work in the daytime as those who wrote at night. They also ignore the negative opinions of other writers couched in as positive terms as the preceding. Only one of these, having more empirical basis than the rest, will be mentioned. G. M. Fenn, shown in the above morning-afternoon list, after experimenting with different methods for some years, off and on, decidedly prefers the daytime. He admits that brilliant work has often been done at night, but, after trial, found the results of a month's day work more satisfactory than an equivalent period of night work.

Parenthetically it may be noted here that the last reference suggests the practical problem of how far regular habits of work have proven beneficial, compared with mere mood-composition. My notes, having bearing on this, are too numerous to make it worth taking up in the short space to which it would have to be confined.[1] This much seems true, however, that the night workers tend markedly to be mood-workers, while those of the day tend more to regularity in production. But that the quality of the latter work is better is not true, though the quantity may possibly be greater.

Before giving my own general view on the matter of the preceding paragraphs, the following passage from a letter of F. W. Robertson,[2] who is listed in the day-night group above, will be of some interest. ''Midday is like mid-life—full of commonplace, of toil and with less of romance. . . . Morning and evening correspond with youth and age, in both of which there is a peculiar poetry. . . . Heaven lies around us in our infancy, and I suppose the mystery of the grave brings heaven again around our decadence, just as the sun approaches the horizon again at evening.'' He thinks the wonder and mystery may seem lacking at midday because the sun is directly

[1] For very many years (30–50), so it is said, the villager of Königsberg was wont to set his watch by the unvarying appearance of Kant for his daily walk. Whether the latter's production could have been so well sustained without this regularity one is inclined in his case to answer in the negative. Chalmers was another shining illustration of the methodical worker. It is said that "so far before him could he see, and so methodically did he proceed, that he could calculate for weeks and months beforehand the rate of his progress and the day when each separate composition would be finished." "His taste for numerical arrangement was exhibited in the most insignificant actions and habits of his life. It regulated every part of his toilet—down even to the daily stropping of his razor. . . . He did almost everything by numbers. His staff was put down regularly at every fourth footfall; and the number of its descents gave an accurate measure of the space over which he had walked. Habit had rendered count an easy, almost mechanical, operation; so that, though meeting friends, and sustaining animated conversation, it still went on." Among the imaginative authors, Anthony Trollope stands as the representative of composing by the watch, which he literally did. Says he: "I have always prepared a diary, divided into weeks, and carried it on for the time I have allowed myself for the work. In this I have entered day by day the number of pages written, so that if at any time I have slipped into idleness the record stares me in the face and demands increased labor." And this he does "whether other business is heavy or light, or whether the book is wanted with speed or not." . . . Much dispute arose as to the quality of Trollope's work, partly prejudiced by his thus violently flying into the face of 'inspiration,' but a just critic must grant that his novels are not lacking in real imaginative character.

[2] S. A. Brooke, *Life and Letters of F. W. Robertson,* **1**: 341–342. 1865.

above and unseen then, and seem more present at the other periods because it is more visible then.

If we admit the fact of a noticeable tendency toward the selection of night for the creative types of composition, it seems to me that the underlying causes, as far as not concerned simply with the chance distribution of individual differences that obtains in all human activities, are more extensive than either of the foregoing explanations implies. Not only 'physical fatigue'—often exhibited in 'high-strung' persons as nervous *excitation,* as well as 'luxurious repose' in others—and mysterious solar influences, appear as factors, but the greater quiet and darkness and the heavenly phenomena—all with their indefinable associations, the prevailing social customs, and the use of artificial stimulants, should not be overlooked.

The first of this last set of causes needs no lengthy discussion. We are all probably more affected by such associations than we ourselves are consciously aware. Such influences as are apt to affect impressionable temperaments at that time are most admirably *suggested* by the following extract from Cable, giving the local and temporal setting of his novel, 'Madame Delphine': "A beautiful summer night, when all nature seemed hushed in ecstasy, one of those Southern nights under whose spell all the sterner energies of the mind cloak themselves and lie down in bivouac, and the fancy and the imagination, that can not sleep, slip their fetter and escape, beckoned away from behind every flowering bush and sweet-smelling tree, and every stretch of lonely, half-lighted walk, by the genius of poetry."

The second and third causes bring me to the expression of the general thesis, which is only this: that excitation *of some sort* is most often the precondition of the highest imaginative work. That one's wits—to speak popularly—are sharpened by either enlightening or enlivening conversation, and that immediately subsequent pen-work is rendered correspondingly easier, will scarcely be disputed, if individual cases of over-excitement be excluded.

And that the prevailing social customs have much favored this sort of excitation may be inferred from remarks of the following tenor. John Wilson[1]: "In Dumfries, as in every other considerable town in Scotland—and we might add in England—it was then customary, you know, with the respectable inhabitants, to pass a convivial hour or two of an evening in some decent tavern or other. . . . The worthy townsfolk did not frequent bar or parlor or club-room—at least they did not think they did—from a desire for drink, though they doubtless took a glass more than they intended, nay,

[1] *Genius and Character of Robert Burns,* 161. 1861.

sometimes even two; and the prevalence of such a *system of social life,* for it was no less, must have given rise, with others besides the predisposed, to very hurtful habits. They met to expatiate and confer on state affairs, to read the newspapers, to talk a little scandal, and so forth, and the net result was, we have been told, considerable dissipation.'' A number of citations of individual cases, in confirmation of the wide occurrence of this custom, could be assembled, if space permitted.[1]

Even less mention can be made, or special illustration given, of the other numerous and well-patronized methods of mental stimulation—from ordinary walking, riding or music to hourly service of blackest coffee, greenest tea or strongest opium, or to constant use of tobacco, before and during composition. The extensiveness of this among the imaginative writers is striking. While these customs, or even the most radical of them, are not confined to the night contingent of the army of the quill, they are most notably represented there. Perhaps a very slight basis of this may lie in the fact that, if one felt some social odium or attribution of weakness might attach to over-indulgence in these directions, it would be easier and more politic to maintain them at night than at any other time. This would also be favored by the closely succeeding chance of 'sleeping off' ill effects that might otherwise be distressing.

The data here are not voluminous nor reliable enough to make possible any scientific determination of the extent to which the various factors are individually involved in the apparent special preference for night-time by imaginative writers, and how far it is a purely instinctive inclination. The information necessary to the solution of this may some time be at hand, but at present we are only in pos-

[1] Extempore rhyming, once so popular in parts of Italy, in reference to our problem has bearing on both evening composition and external excitation. This description—much shortened—is to be found in Spence's *Observations, Anecdotes and Characters*, pp. 248–251: "The improviso . . . poets in Italy are actually what they are called . . . and do it with great emulation and warmth, generally in octaves, in which the answerer is obliged to form his octave to the concluding line of the challenger; so that all the octaves after the first must be extempore, unless they act in concert together. Our method is to create our thought at the enemy's seventh verse: then we have the idea, the rhymes, the words and the verse to think of, only while our opponent is repeating his last line, which we take no manner of notice of at all. We almost always do better the second half hour than the first, because one grows warmer and warmer, to such a degree at last that, when I have improvised all evening, I can never get a wink of sleep all the night after. . . . Cavalier Perfetti, of Sienna, the best in Italy at present, . . . is so impetuous in improvising that sometimes he will not give way for the guitar" (Signor Nanechi).

session of the practical fact that many writers do actually prefer, use and do their best work in, the night hours.

A noteworthy exception to this fact is found in the case of the female authors, indicated in the above lists by *F*. In all there are 18, distributed as follows: 10, morning; 1, afternoon; 2, night; 2, morning-afternoon; 3, whole day. Remembering that the last five belong partly in the first group, and that the night groups have slight representation, it will be seen that the early hours of the day are decidedly in the ascendency as to preference. This is quite in harmony with what has preceded, in this paper, regarding the peculiarities of the female diurnal curve.

Many individual incidents, of intrinsic interest and of some scientific value, must be omitted; but two short instances of what is referred to may be transcribed. T. J. Hogg,[1] reports of Shelley that "at 6 P.M. he would suddenly compose himself, even in the midst of a most animated narrative or of earnest discussion; and he would lie buried in entire forgetfulness, in a sweet and mighty oblivion, until 10, when he would suddenly start up, and rubbing his eyes with great violence, and passing his fingers swiftly through his long hair, would enter at once into a vehement argument, or begin to recite verses . . . with a rapidity and an energy that were often quite painful." Sir Walter Scott[2] was furnished by Comte de Tressan with this description of the late days of A. R. Le Sage, the noted French novelist: "Mons. Le Sage, awakening every morning as soon as the sun appeared some degrees above the horizon, became animated, acquired feeling and force in proportion as that planet approached the meridian; but as the sun began to decline, the sensibility of the old man, the light of his intellect, and the activity of his bodily organs, began to diminish in proportion; and no sooner had the sun descended some degrees below the horizon, than he sunk into a lethargy, from which it was difficult to arouse him." This, if true, is certainly a remarkable instance of diurnal rhythm.

This must close our account with the authors. On the whole, it appears that they elect the hours most frequently used by students for their study.[3] It is possible that we have here suggested, not the most 'ideal' program, but the most practical one. For those who

[1] Quoted by E. T. Mason in *Personal Traits of British Authors*, **1**: 110. 1885.

[2] *Lives of Eminent Novelists and Dramatists*, 596. Undated.

[3] It was said above that some writers were included whose actual working hours were used, in lieu of a distinctive preference. By far the larger part of these occur in the two longest day groups, and especially in the whole-day group. The percentage of the latter group is thus too high and the others—particularly morning and night, as judged from known cases—are correspondingly too low.

can not stand a sixteen-hour stretch, it may be better to put the relaxative period as an interlude rather than as a postlude. Productively, whether a period of relaxation in the midst of the day's work is good or bad depends on the individual make-up and can not be judged aside from that; but the 'productive' standpoint is the best one to take, if it be true that 'we live in deeds and not in years.' Productively, if not indeed constitutionally also, too much rest is as injurious as too much work. The fact is frequently overlooked that much rest, habitually indulged in, tends to beget a more-rest disposition, just as, so the economic moralists tell us, a person's needs are likely to increase with his wealth. It is important to remember that the psychological phenomenon of practise effect acts in rest and work in general just as it does in the particular manifestations we have been dealing with above. In either instance, a limiting level of productivity is eventually reached. In most lives these matters are left to regulate themselves, without a great amount of conscious or systematic direction. We make ourselves believe that this is always due to external conditions, but we have examples, several of which were mentioned above, of lives successfully ordered by intelligent choice. The poetic temperament is peculiar and such regularity would be unusual and possibly disastrous in many cases, but with all persons it is probable that more thought and self-experimentation along this line would result beneficially.

No other pertinent work on the diurnal course of mental efficiency has been found save that to be cited under 'fatigue.' The testing of such mental complexes as have been referred to is deemed important in proportion to the homogeneity of the tested group, and the preceding discussion has been limited for the most part to persons possessing considerable intellectual culture. Psychologically it would be valuable if tests were devised which would place on a comparable basis the mental operations of classes widely variant. This might lead to some fundamental knowledge as to the existence or non-existence of certain general or essential forms of mental process, and of their kinds, degrees, relations, etc., in any given activity.

III. Brief Summary

It is clear that whatever conclusions are made, respecting the data in this section, will be less firm than those of the one preceding. Still, there are some definite indications. As to the simpler mental functions first mentioned, one would infer that those which in their testing involve the use of motor elements tend to follow in speed the motor type of midday maximum, though making it a little earlier,

while in accuracy the morning is favored, though but slightly. In the more strictly mental and in the more complex activities, there is a similar inclination to the morning periods both in rate and in accuracy. Adult students and authors seem to think the earlier part of the day best for their respective employments, but in practise both draw heavily on the night period, while in the case of females and children the morning maximum seems to be the rule. The suggested morning efficiency of adults does not hold good, however, of the first moments after arising, where there still appears an inertness comparable to that on the motor side, though less evident and more evanescent.

NOTE

There came to my attention as this paper was about to issue from the press, the interesting work of J. A. Bergström on 'A Study of Mental Activity,' in the *Amer. Jour. of Psych.* for 1894. Only chief and brief cross-references can be made. For rate of movement, a simple test was used; for old associations, classification of words, and the reading, adding and multiplication of numbers; for new associations, learning number series and nonsense syllables and the sorting of cards.

In movement, J. A. B. made this record, in number of strokes per minute,—7 A.M., 262; 8, 272; 10, 278; 12, 267; 2 P.M., 277; 4, 270; 6, 269; 8, 260; 10, 260 (p. 258). A subject of Mosso's made this record at 8, 10 and 12 A.M.,—260, 268, 268 (p. 261—cf. p. 17 above).

In memory of nonsense syllables, E. C. S. progressively loses ability during the day (p. 249); while J. A. B. is best at 8 A.M., and worst at noon and 6 P.M. (p. 256). In old associations (sorting cards), 3 subjects diminish in ability from morning to night, 1 increases, 1 is best in afternoon and worst at night and 1 is the opposite (p. 249); J. A. B. tends to follow his movement course, but the maximum is at 6 P.M (p. 258). For the other associational tests, J. B. A. found a uniform curve: low ability at 8 A.M., increasing to 10, decreasing to 12, increasing to 2 (same as 10), then a slight decline to 6 P.M. (p. 256—cf. p. 53).

Some of his more general conclusions follow.

No necessary correspondence between pulse and mental rate (p. 260).

"Heerwagen sent out the following: What part of the day do you find mental work easiest? 182 said the morning, 133 the evening, 6 the afternoon, 43 noticed no difference, while 28 found it easy at all times. Professor E. Barnes, in a study of the intellectual habits of Cornell students, received in reply to the same question, 66 votes for morning, 6 for afternoon and 39 for evening. The average student, he says, begins work at 8, but is in doubtful condition, is best at 9 and at 10 is still in good condition, at 11 is tired, and is at his worst at 12. He works from 3 to 5 P.M., but in inferior form; after supper, he goes to work at 7 and reaches his best at 8; from 9 he is not at his best, and retires at 10:30" (p. 262—cf. p. 59).

"The familiar 'warming up' to work is probably to be explained in large part by these facts of nervous activity '(summation phenomena). Féré notes that reaction time does not reach its greatest rapidity till the stimulating influence of light and heat has operated for some time. Nocturnal paralysis and morning tire are explained as exaggerated phenomena of this sort' (p. 264—cf. p. 71).

"The daily mental rhythm is much influenced by habit (p. 266—cf. p. 74). These habits (of authors), however acquired, evidently have great power of distracting the attention if they are not satisfied, and so retard work" (p. 267—cf. p. 76).

No apparent effect of fatigue upon sensory discrimination (p. 266—cf. p. 79).

"Stimulations which would inhibit in normal conditions, in fatigue produce reinforcement. The fact that reinforcements of sensations and muscular movements are more prominent in neurasthenic and hysterical persons seems to be paralleled here. The greater excitability and sleeplessness in fatigue are another illustration" (p. 263—cf. p. 88).

"There is no *general* type of daily rhythm, and individual differences of the most striking sort occur" (p. 262—cf. p. 95).

These results and conclusions largely agree with my own.

D. CHIEF CAUSAL FACTORS IN THE DIURNAL EFFICIENCY CURVE

THE main effort up to this point has been to bring together the data that appear to have most direct bearing on the question of diurnal rhythms. It is only after such an assemblage of the facts that a discussion of the causal factors can profitably be begun. The problem is of such nature that it could utilize every known psychological fact, on the one side, and run into every possible theory, on the other, if its utmost reaches were sought. Yet, there is no ultimate satisfaction in a purely factual description, correct to the last word—there is always the demand for explanation, or deeper facts. It is to an endeavor to meet this demand in some degree that the present section is mainly devoted.

I. NIGHT-DAY RHYTHM—SLEEP AND ACTIVITY

A first approach to a solution is made when it is intimated that the day-night process exhibited by nature is the primary condition upon which depends the daily broad human rhythm of sleep and activity. The wakeful period is the only one that has hitherto been touched in this paper, but the variations occurring therein can not be explained without reverting to the preceding period of inactivity.

Donaldson[1] gives this physiological explanation of the whole matter: "After recuperative sleep the cells in the nervous system are full-sized and granular, blood flows with a medium pressure through the nerve centers; slight stimuli elicit a ready response and there are general sensations of well-being and vigor. From the beginning of the day the process of running down goes on; all the constant stimuli hasten it, meals retard it, drugs modify it, per their nature." The night inactivity is due to accumulation of waste products of the day's activity, and sleep to cerebral anemia caused by withdrawal of the blood from the brain at this period. He thus makes one fundamental, long rhythm—a gradual depression toward night and recuperation by sleep.

All sorts of things have been asserted about the office of sleep in the human economy,[2] and it is obvious that it plays a highly beneficial part. Theoretically, Donaldson's view is most credible, but experimentally it proves untenable as a general expression of the

[1] *Growth of the Brain*, 322–323. 1898.

[2] For the most peculiar, see Bigelow, *The Mystery of Sleep*. 1895.

facts. Adults are probably not at their best on arising and frequently show highest abilities in the evening. Aside from possible histological evidence in its favor, the strength of the opinion that early-morning efficiency is highest seems due to the failure to apply exact measurements, leaving judgment to the feelings, which are confessedly unreliable. One can not tell just how much he is doing by the effort he seems to be expending, as various sorts of delusional and reinforcement effects show. The early morning may be accompanied by a not unpleasant ennui, like that of a convalescent, which would not at all suggest the idea of inefficiency, while the afternoon is often accompanied, for many, by positively disagreeable feelings of weariness, which emphatically lead to the idea of simultaneous inefficiency. Inefficiency results from weariness, but the amount tends to be overestimated in our minds while the inefficiency of the morning tends to be relatively underestimated.

The presence of inefficiency after sleep is shown not only in the foregoing pages, but was also found by Roemer,[1] experimenting on this matter directly. He sought to determine psychic efficiency (1) after normal sleep and (2) after curtailment of the normal period of sleep at the morning and night ends. His tests were memory of figures, addition, controlled reaction-time and association. His results are not given tabularly but stated thus:

(*a*) The condition shortly after arising from normal sleep is one of more or less weariness (*Müdigkeit*).

(*b*) Cut off sleep at the night end, and little alteration occurs because the loss is made up by deeper subsequent sleep.

(*c*) Cut off sleep at the morning end, and fatigue (*Ermüdung*) results.

Later[2] he essayed to ascertain the effect of afternoon sleep on performance and found—by tests of memory and addition—that a male, 'normally feeling languid after lunch,' showed marked increase of ability after a nap; while a female, not subject to such languor, showed the opposite effect.

From these experiments he concludes that *Müdigkeit* is a brain condition, while *Ermüdung* is due to tissue consumption in the organism. As the connotation of 'fatigue' has been narrowed since 'weariness' has received acceptation, so it should be still further restricted by another characterization representing this morning condition, which may well be termed 'inertness.' This carried-over sleep effect

[1] 'Ueber einige Beziehungen zwischen Schlaf und geistigen Thätigkeiten,' *Vortrag, Cong. für Psych.* 1896.

[2] 'Experimental Studien über den Nachmittagsschlaf,' *Allgem. Zeitschrift f. Psychiat.*, **53**: 860–863. 1897.

seems something different from the weariness and fatigue that result from the day's activity. This matter will be taken up again soon. In respect to Roemer's second investigation, regarding afternoon sleep, the alleviation of the condition of fatigue in one subject, and the initiation of inertness in the other, may be sufficient to explain the results.

Various researches on sleep have established the fact that by far the soundest portion during the night is that of the first three hours. For instance, this was found by Michelson[1] to be true for four subjects. The writer has chosen from his plotted curves one which would be more typical of their average tendency, if it reached a maximum at the second hour instead of the first; but it was selected rather with a view to illustrating a conception of how early morning inefficiency arises and how the start of the fundamental diurnal curve is determined.

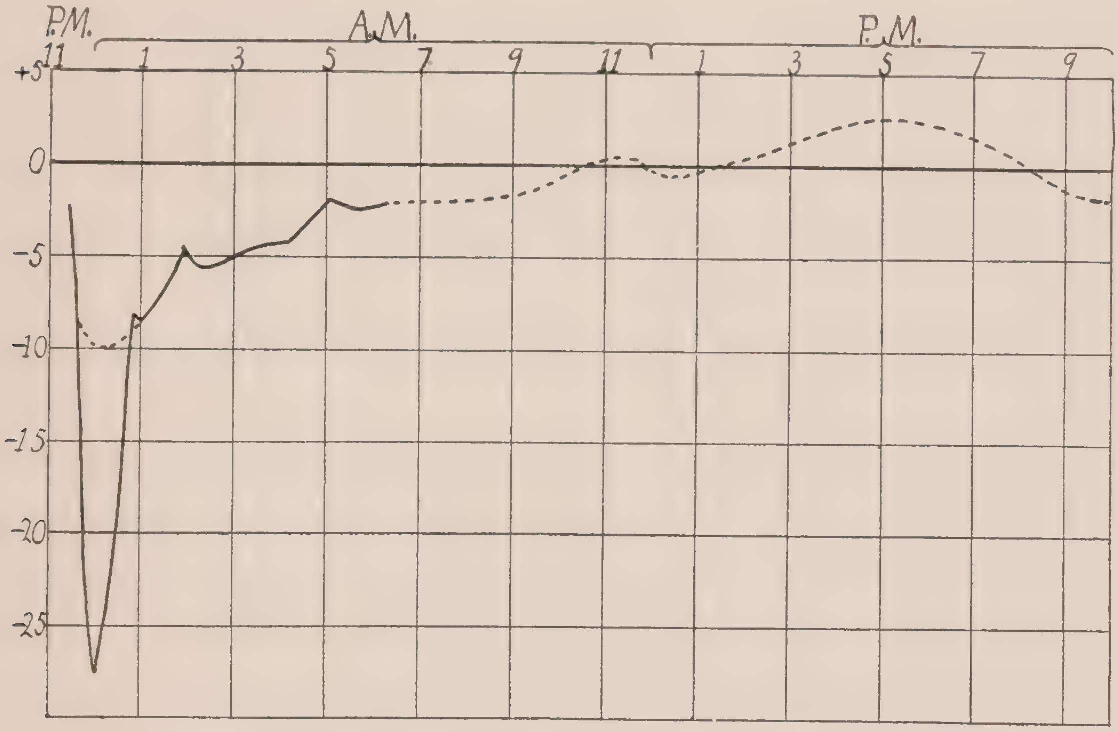


FIG. 5. The Hourly Depth of Sleep—after Michelson.

If this curve of degree of unconsciousness be conceived as representing a person's degree of physical inefficiency, it will be noted that normal ability, designated by the base line, is not reached on arising, but that the curve is slowly approaching it at this point and at the same general rate would reach it about 10 or 11 A.M. The facts already cited lead us to suppose that this is exactly what happens. Sleep imposes an inertness, more or less pronounced, whose influence but gradually passes away in adults on arising. This first condition represents, as it were, an adaptation of the organism to nocturnal

[1] 'Ueber die Tiefe des Schlafes,' *Psych. Arbeiten*, **2**: 1 Heft.

inactivity, to remove which some little time is required after awakening to the exigencies of active life.

As the period prior to awakening can be thought of as one of dwindling negative internal stimulation—of passing sleep effect—so may the subsequent period be considered as one of increasing positive auto-stimulation—of growing awakeness. It would not follow—though it would be suggested—that because sleep exhibits different levels of consciousness, therefore wakeful life should do the same, but the fact is experienced by all and needs no proof. The inner tendency to 'warming up,' due partly to habit, is amplified by the cumulative effect that succeeding stimuli have on us—an effect which is seen in its simplest and most definite form in the well-established fact of 'summation of stimuli,' demonstrated by physiological experiments on muscle and nerve. The physiological discharges take place more and more readily during the morning, till a certain level is reached for the individual, or accidental causes of depression interfere. In short, it may be said that the night's general habit of inactivity and the night's immediate sleep effect are instrumental in imposing on us a morning period of physical inertness, more or less reflected in the mental life; and that the general habit of day activity together with its frequently repeated stimulations tends increasingly to lead us to higher levels of efficiency—up to a certain limit.

This tendency meets with modifying and restricting influences, however, the relative force of which determines the actual form of the efficiency curve for each individual. When one reviews some of the things which can profoundly affect the human organism in its functionings, the first thought is that there could be no great part of the individuals in any group who would probably conform to any one type of curve. This seems to be true when any great refinement of it is undertaken. But in the broad sweeps suggested, there is still chance of coming to ground common to many, as was shown in the previous paragraph. Personal habits are accidental as far as a common curve is concerned, and must therefore be disturbing elements. They can not profitably be treated apart from the actual cases, save in a general way, but the universal custom of eating offers something more substantial for discussion.

II. Habits, Meals, etc.

The effect of habit was used as a partial basis for the preceding statements. It is also applicable when the habit is more special and is voluntarily assumed. If a person, with afternoon maximum strength, were consistently and long to exercise only in the morning,

his curve would very probably be altered accordingly. Students are proportionately much better at night in mental labor than people unaccustomed to study then. Writers who have set the morning as the time for composition in spite of feelings to the contrary, come eventually to consider it their best period and work then with the least friction. Illustrations might be multiplied, but it seems enough to say that, in general, just as physiologically there occur periodic hints of meal-time—even to the point of faintness and sickness with some people, if the customary time be passed by so much as an hour—so it is probable that in all cases of habituation similar phenomena occur which, with their mental accompaniments, become the sources of secondary fluctuations in the individual curves.

"The noonday dinner gives one both a bad stomach and a bad conscience, and results eventually in an empty head." So says O'Shea,[1] after much attention to the food question in relation to mental economy. Roemer[2] experimented eight days on the effect of food, using as tests half hours of addition at 9, 10, 11 A.M. and 12 M.—four days with breakfast and four days without, *alternately*. Table XXIX. shows, first, the absolute number of additions and, second, the reduction of the same to percentage of the first hour's performance.

TABLE XXIX. EFFECT OF LOSS OF MEALS ON ADDING ABILITY—AFTER ROEMER.

	Without food.				With food.			
	9 A.M.	10:00.	11:00.	12:00.	9 A.M.	10:00.	11:00.	12:00.
Number added.	6,741	5,856	5,707	5,990	8,695	8,453	7,906	7,831
Per cent. of first hour.	100	87	84	90	100	97	91	89.5

The series of experiments was too short to prove anything, but the results, in the light of the noon records, scarcely seem to suggest his conclusion of a beneficial food influence so much as that the relatively bad records at 10 and 11, of the days without food, were dependent on the disturbance consequent upon the irregularity. It is but fair to Roemer to say that he admits this as a possible factor, but he fails to give it sufficient weight.

Kraepelin[3] holds a similar view as to food effect: "The psychic disposition of the individual shows in general during the day quite definite changes—an increase of performance ability till about noon, a quick fall after lunch, a new increase in late afternoon and a final

[1] *Op. cit.*

[2] Weggandt, 'Roemer's Versuche über Nahrungsaufnahme u. geistige Leistungsfähigkeit,' *Psych. Arbeiten,* **2**: 695–706. 1899.

[3] 'Ueber Ermüdungsmessungen,' *Archiv f. die gesamte Psych.,* **1**: 9–30. 1903.

evening fatigue. Regeneration is accomplished by food on the one hand and by sleep on the other.'' He later alters this; namely, he finds an increase, both physical and mental, after each meal. This is the source to him of the diurnal variations.

That meals have an influence is true, but that it consists in an immediate tendency to increasing ability is not clearly seen. Finzi,[1] for one, says just the opposite—that they reduce the speed of all functions. Many, if not most, experimenters on the effects of different agencies (alcohol, tobacco, food and foodstuffs, drugs, sleep, etc.) fall into what seems to be a serious error, already mentioned. That is, the fact is overlooked that *elimination of customary influences* affects the organism as radically as does its subjection to positive stimuli. The immediate effect of breaking a habit is apt to be detrimental, whatever the habit may be. This, it may be said in passing, is one of the most subtle—and vitiating—elements of *all* experimentation. When a smoker quits that habit for a few experiments, two causes figure in the result; one the change of a particular condition—which is the one aimed at—and one the alteration of an habitual condition—which is the one so frequently ignored. There is reaction to the one as to the other, physiologically and psychologically. The writer found in a five days' course of fasting, by both objective tests and subjective feelings, that the greatest disturbance, mentally and physically, occurred on the first and second days —the latter particularly—after which gnawings, headaches and nausea began noticeably to subside and the abnormal condition tended appreciably to become normal to the end of the course. Data obtained only from those first few days would have been quite misleading.

Some good evidence on the persistence of habitual periodicity in activity is contained in an article by Patrick and Gilbert on the 'Effect of the Loss of Sleep,'[2] though the authors do not utilize the material for this purpose. Two subjects, A. G. S. and G. N. B., were kept awake 72 hours and various tests were given them every 6 hours. On successive days, the *worst* records were made at the following hours, showing the subjective disturbance to be greatest at the periods ordinarily devoted to inactivity—to *sleep*. The first day, being unaffected, is omitted.

1. Adding.

    A. G. S.—3 A.M., 3 A.M., 9 P.M. (last test taken).
    E. N. B.—3 A.M., 3 A.M., 9 P.M. (last).

[1] *Normalen Schwankungen der Seelenthätigkeiten*, Reprint, p. 14. 1900.
[2] *Univ. of Iowa Studies in Psych.*, 1: 40–61. 1897.

2. Hearing.
   A. G. S.—3 A.M., 3 A.M. (none after 3 P.M.).
   E. N. B.—3 A.M., 9 P.M., 3 P.M. and 9 P.M. (last).
3. Discrimination of letters.
   A. G. S.—3 A.M., 3 A.M., 3 A.M. and 9 P.M. (last).
   E. N. B.—3 A.M. and 9 P.M. to 9 A.M., 9 P.M. to 9 A.M. and 9 P.M.
4. Strength.
   A. G. S.—3 A.M., 3 A.M., 9 A.M. (none taken at 3 A.M.).
   E. N. B.—3 P.M., 9 A.M., 9 P.M. (last).
5. Memory.
   A. G. S.—3 A.M., 3 A.M. and 9 P.M. to 3 A.M., 9 P.M. (last).
   E. N. B.—3 A.M. and 9 P.M., 3 P.M., 9 P.M. (last).

The times of the best records point just as strongly in the same direction. These results, aside from the effects of loss of sleep, show the recurrent nature of an established habit and how important must be its influence in every individual curve.

By all my subjects, the heaviest meal of the day was eaten about 6 or 7 P.M.; hence the fourth period should show the best work, if meals alone cause the differences. Subjects I. and A ate very light lunches, yet the 5 P.M. period is the best, as to strength at least. Lombard[1] seems to be right when he says, "the temporary influence caused by a meal can not long delay the decline nor can it hasten the increase of strength which is caused by the diurnal alterations of the power." Rest and social elements are also involved in the nature, amount and permanence of the change in ability wrought by the meal interval.

III. Fatigue and Feelings of Fatigue

Granted that periodical changes in individual curves of efficiency do exist for time of day, it is evident that no credible theory of their cause could be constructed without reference to those effects, to which all are subject, that have been treated usually under the head of 'fatigue.'

Chronologically, the study of diurnal variations in ability originated from an interest in the problem of fatigue. One can not look over the literature of the subject without noting that the experiments on motor power, following the introduction of the Mosso ergograph in 1890, were largely influential in turning attention to the measurement of human functions, mental even more than physical. Some earlier work had been done by Sikorsky ('79), Hodge ('87),

[1] 'Some Influences affecting Voluntary Work,' *op. cit.*, p. 30.

Galton ('88), Oehrn ('89), and a few others, but did not attract much attention. In Germany, an immense impetus was given to such investigations by pedagogical needs and, indeed, the whole problem of periodicity and fatigue may be said to have taken its rise from this relation to school life, and its solution to have its most valuable application there. Therefore the treatment of this section will be rather extensive, though it will be impracticable even to refer to the mass of original work in this direction undertaken since 1890.

1. *Muscular Fatigue*

Fatigue tests here are, in one aspect, strength tests, and, therefore, have already received some mention. By far the greater amount of the work in this immediate connection has been taken up with a view to determining the location of the seat of fatigue —whether it is central, neural, muscular, etc. Ultimately these considerations must be utilized in any thoroughgoing treatment of the diurnal problem, but the same can as truthfully be said of any group of facts concerning the living being, if the question be in no wise limited. So far, then, as these experiments have been carried out without reference to time of day they must be ruled out, but so far as they have been used as mental measures, they will be discussed immediately below.

2. *Mental Fatigue*

1. *Measured by Motor Inefficiency.*—One primary question, whether decrease in muscular power is a trustworthy sign of fatigue in mental function or not, has sometimes received empirical consideration, but quite as often an affirmative answer has been assumed as true.

Bolton,[1] in the course of his theory of motor development, says: "Tests of motor power may be used as measurements of intelligence or mental alertness. . . . As substitutes for the old-fashioned methods of examination . . . tests of physical endowment and of general healthfulness of body seem to offer the most promise. . . ."

Lukens[2] is authority for the statement that Kemsies with the ergometer found distinct correlation between mental fatigue and lessened muscular power and that 'the ergometer showed the fatigue in certain cases to have continued several days' after some insevere night mental tests.[3] What he found the following

[1] 'Motor Power,' *Am. Jour. of Psych.*, **14**: 615–631. 1903.

[2] 'The School Fatigue Question in Germany,' *Ed. Rev.*, **15**. 1898.

[3] Bettman (see Bibliog., Part E) also says that, though no permanent injury to ability resulted from night tests in adding, 'a very strong fatigue affected the disposition for several days following.'

mornings was probably not residual fatigue so much as the normal condition of inertness. He and others have arranged curricula in accordance with the results of such ergographic tests after recitations in the various branches.

Christopher and Smedley, in the articles noted above, make the assumption of such a direct relation between mental fatigue and motor force, the former advising that 'physical condition should be a factor in grading, especially for entrance to first grade,' while Smedley says that 'certain parts of the school day, when pupils on the average have a higher storage of energy than at others, should be utilized for the highest forms of educational work.' The one assumes that mental fatigue is present when the ergographic records are low; the other, that it is absent when they are high.

Ellis and Shipe[1] assume throughout their trials that fatigue is present in the afternoon, and hence when the tests fail to show it, the tests are voted valueless. They took reaction-time and ergographic tests on six subjects for five days, twice a day (? A.M. and 12:30 P.M.) and found that "these tests seem to show that the students (college) were as fresh at noon as at the beginning of the day. Their appearance and feelings belied their results" (p. 234). Such acceptance of the emotional evidence of fatigue is an easy but serious mistake to make. Various writers[2] have pointed out the need of observing the distinction between fatigue proper and the feelings of fatigue.

Where my own subjects noted mental depression or even headache on their records, the figures rarely failed to show a high grade of muscular performance at the time. But the younger the individual the more prone he is to follow his feelings, in the quantity and quality of his work. Especially was this noticeable among the coin-case workers, whose every (seen) gape and sleepy look was duly registered. Still, it is yet to be proven that there is a causal connection between mental and motor deficiency such that one may be an accurate measure of the other.

2. *Measured by Sensory Inefficiency.*—Another conception is that the degree of insensitivity of the skin is a measure of fatigue. Griesbach[3] was the originator of the esthesiometric method of studying fatigue and performed many experiments with it. He determines the least distance on the skin at which the two points of the

[1] 'A Study of the Accuracy of Present Methods of Testing Fatigue,' *Am. Jour. of Psych.*, **14**: 232–245. 1903.

[2] Cowles, MacDougall, Dearborn, Thorndike, Kraepelin, Roemer, etc.

[3] *Energetik und Hygiene des Nervensystems in der Schule*, S. 1–95. 1895.

instrument, on being gradually approached from a point where they are easily distinguished, are perceived as two; or the greatest distance at which two points are perceived as one, on being gradually separated from below the so-called threshold. His results were thought remarkably decisive and consistent, so much so that, like his followers Vannod and Wagner with the same instrument, and like Kemsies and others with the ergograph, he was able to obtain a fatigue coefficient for each branch of study and then to assign each to its proper place in the daily school routine. The only trouble is that the different results do not accord.

Griesbach found that the sensitivity changes little during the day under normal conditions, but gradually decreases under school conditions. He tested the pupils, professors and mechanics of a school, on the forehead, nose, cheek, underlip, ball of thumb and ball of forefinger. By averaging these six determinations he obtained a very typical curve of the changes in the threshold. The following figures show the resulting values in millimeters.

Table XXX. Esthesiometer Tests—Revision after Griesbach.

7 A.M.	Math.	8 A.M.	Latin.	9 A.M.	Greek.	10 A.M.	Religion.	11 A.M.	Physics.	12 M.	Rest.	1 P.M.	Rest.	2 P.M.	Rest.	12 M. Next Day.
5.8		8.0		10.0		10.8		7.3		9.8		—		3.5		2.7

Griesbach, therefore, demands (1) no school work in the afternoon, (2) later beginning in morning—on account of residual fatigue from the previous day, (3) abolishment of examinations, (4) less home work and less learning by heart. Special attention is called to the high afternoon sensitivity compared with that of the early morning—true both of the work-day and the rest-day following. His method has been much tried and criticized, but only a few of the leading articles can be referred to.

MacDougall,[1] after adverse criticism of other methods, says of Griesbach's that it is 'decidedly satisfactory'; that by it can be found the best hours and days for study and the length of study periods proper for different ages. He produces no experimental proof of his own.

Leuba[2] attacks the method and results. He tested three adult male students for fourteen days, at 9 A.M., 11 A.M., 1 P.M., 5 P.M. and 9 P.M., on cheek and thumb, 6,000 judgments in all. He found

[1] *Am. Jour. of Physiol.*, **19.** 1898.

[2] 'Validity of the Griesbach Method of Determining Fatigue,' *Psych. Rev.*, **6.** 1899.

divergent results as between cheek and thumb and as between one and two point determinations on the thumb alone, and his results were also diametrically opposed to those of Griesbach, Vannod and Wagner. They showed, on the whole, a marked increase in sensitivity up to 5 P.M. and thence a steady decrease. The results for this group and for the one described below are graphically represented in his publication, but have been transmuted into figures by the present writer, as indicated in Table XXXI. Work and rest days are given separately. The second series was on six adult female students, 2,000 judgments, at 8:15 A.M., 10:15 A.M., 11:15 P.M. and 1:15 P.M. It gave similar results, diverse for forehead and cheek as to the single individuals, but showing considerable constancy in the total curves. The females also start with a relatively low sensitivity and increase as steadily as the males.

TABLE XXXI. ESTHESIOMETER TESTS: THRESHOLD IN MM.—REVISION AFTER LEUBA.

Male Subjects.	9:00 A.M. Work.	Rest.	11:00 A.M. W.	R.	1:00 P.M. W.	R.	5:00 P.M. W.	R.	9:00 P.M. W.	R.
1	14.5	14.0	15.1	13.3	14.5	13.6	14.0	14.1	14.4	14.6
2	15.8	15.4	15.2	15.5	15.7	16.2	14.9	16.1	14.8	16.6
3	8.0	8.4	7.5	7.2	7.4	7.1	7.1	6.7	8.1	7.6
Average.	12.8	12.6	12.6	12.0	12.5	12.3	12.0	12.3	12.4	12.9
Female Subjects.	**8:15 A.M. Forehead.**	**Cheek.**	**10:15 A.M. F.**	**C.**	**11:15 A.M. F.**	**C.**	**1:15 P.M. F.**	**C.**		
1	16	22.0	15	22.0	14	20.5	14	20.5		
2	11	13.0	9	11.0	11	15.0	10	12.0		
3	7	11.0	6	11.5	4	8.0	3	8.8		
4	12	21.9	17	21.0	14	22.0	13	22.1		
5	8	10.0	6	8.8	7	8.0	8	8.0		
6	8	11.0	5	11.0	5	11.1	5	9.0		
Average.	10.5	14.8	9.7	14.2	9.2	14.1	8.8	13.4		

Germann[1] used both one and two points, noting the number of errors at the threshold. The experiments were made on an adult female student studying eight or nine hours daily; she was tested at about 8:30 A.M. and 9:30 P.M.; 2,450 judgments were made. Table XXXI. gives the results of fourteen days, in each of which a pair of tests were taken.

TABLE XXXII. ESTHESIOMETER RECORDS—AFTER GERMANN.

Errors.	A.M. = P.M.	A.M. > P.M.	A.M. < P.M.
Total.	4	8	2
2-point.	1	9	4
1-point.	2	9	3

[1] 'On the Invalidity of the Esthesiometric Method as a Measurement of Mental Fatigue,' *Psych. Rev.*, **6**. 1899.

This means that the percentage of *erroneous* judgments in the morning was equal to that in the evening on four days; greater on eight days; less on two days; etc. Hence he concludes that "in at least one normal case the percentage of errors in cutaneous tactile discrimination bears no constant nor even relative correspondence to the mental fatigue experienced by the subject." This conclusion is hasty, as it possibly confuses fatigue and feelings of fatigue and fails to take account of the state of inertia which has been emphasized as occurring early in the morning.

It is suggested, therefore, that the morning insensitivity observed by these various experimenters is not at all a symptom of technical, nor of 'residual,' fatigue, nor yet of subjective weariness, but rather of inert physical condition unconnected directly with any one of them. It is also a mistake to assume that insensitivity can arise only as a result of fatigue, and just as much a mistake to suppose that much fatigue is necessarily present in adults in the afternoon or after several hours' effort. Many other authors also have demonstrated the unsafeness of this method for measuring mental fatigue.[1]

3. *Measured by Mental Inefficiency.*—A closer approach to a purely mental test of fatigue is found in the reaction-time or association-time method first used by Cattell.[2] In a course of experiments with different sorts of stimuli, reactions (1,950 in all) were continued for a whole day, from 7:30 A.M. to 8:30 P.M., with short intervals for eating. The results are thus summed up: "The first result to be noted is the very slight effects of fatigue; in no case is the time lengthened more than a couple of hundredths of a second and the mean variation is but little increased. We reach the unexpected conclusion that the processes which are most automatic—naming colors and simple reaction-time to sound—are the most affected by fatigue."

This method was also employed by Roemer and by Ellis and Shipe.[3] The latter determined the reading time for words of four letters, in morning and at noon, and state their results in the words quoted on page 79, above. In regard to a second series of various tests, they say, "Of 24 perfect records reaction-time was shorter 14 times at 5:30 P.M.; mean variation less 13 times; total figures added, more 17 times; more added correctly, 15 times; more cubes written, 19 times; more nonsense syllables learned, 15 times. One of the best records came just after a long, hard examination (in the

[1] As Cattell, Ebbinghaus, Kraepelin ('99), Bolton, Meumann, Kraepelin ('03).

[2] 'The Time taken up by Cerebral Operations,' *Mind*, **12**: 44. 1886.

[3] *Op. cit.*

afternoon) for which the student, after working and worrying all the day before had continued work till 2 A.M. the night before.''

Later, seven subjects were tested (1) during a week before March examinations, (2) during the examination week and (3) during the one following. The results practically agreed with those of previous series, and the authors report 'the same lack of agreement between tests and the same failure to indicate fatigue in the afternoon.' If they 'failed to indicate fatigue' they must have agreed somewhat, it would seem.

Then three subjects were used (four, three and two days, respectively) at 9–10 A.M. and 5–6 P.M., and results were obtained 'equally inconsistent with each other and with the undoubted facts.' These last citations show the assumption in the writers' minds that fatigue is the normal afternoon condition in the case of all adult students.

It appears from their reports that the afternoon reactions and results in general were superior to those of the morning, even though the morning tests were taken rather late. Their series of experiments were short but, as far as they go, confirm the views expressed in the previous portions of this paper.

One of the earliest tests to be used was that of 'dictation exercises,' introduced by Sikorsky in 1879—the first attempt at objective measurement of mental fatigue. It was later used by Oehrn ('89), Hopfner ('94), Friedrich ('96), and preferred to all others by Henri and Binet ('98). According to its advocates, it is easily given to groups, easily checked up, easy to understand, has no practise effect, and the different characters of the errors show the different types of fatigue (as for arithmetic, gymnastics, etc.). Only those of Sikorsky and Friedrich offer direct evidence on the problem in hand.

Sikorsky, according to Binet,[1] gave 500 dictations to six classes, the members ranging in age from nine to sixteen years, at 9 A.M. and 3 P.M., before and after the school session. The number of errors made by each class is given in the following table.[2] Binet classified these into phonetic (omissions and substitutions of letters), graphic (in written form, etc.), psychological (omissions or substitutions of words), indeterminate (all others). These are also shown in the table in per cents.[3]

[1] *La Fatigue Intellectuelle,* 288. 1898.

[2] The figures are evidently percentages of something: Binet does not say what.

[3] Neither of the revised columns totals 100 per cent.: Binet does not say why.

TABLE XXXIII. FATIGUE—MEASURED BY DICTATION EXERCISES.

Binet, after Sikorsky.				Binet, revision after Sikorsky.		
No. of Class.	9 A.M.	3 P.M.	Per Cent. Difference.	Kind of Error.	9 A.M.	3 P.M.
Class 1	123.5	156.7	+33.2	Phonetic.	62.6 %	77.3 %
" 2	121.5	145.3	+23.8	Graphic.	8.9 %	11.3 %
" 3	72.4	102.8	+30.4	Psychic.	4.5 %	8.9 %
" 4	66.5	94.2	+27.7	Indeterminate.	6.0 %	11.9 %
" 5	61.4	81.0	+19.6			
" 6	45.7	80.0	+34.3			

This table interprets itself. The differences in efficiency are seen to be very large, uniformly so, and can leave no doubt as to the correct inference. But still greater differences were found by Friedrich with a class of 51, averaging ten years of age.

TABLE XXXIV. FATIGUE—PER ERRORS IN DICTATIONS—BINET, AFTER FRIEDRICH.

Before Classes.	After 1st Hour, 0 Recreation.	After 2d Hour, 1 Recreation.	After 2d Hour, 0 Recreation.	After 3d Hour, 2 Recreations.	After 3d Hour, 1 Recreation.	After 3d Hour, 0 Recreation.	Before 1st Hour.	After 1st Hour, Gymnastics.	After 2d Hour, 1 Recreation.	After 2d Hour, 0 Recreation.
45	70	123	158	112	166	184	65	152	109	185

These figures serve to show the effect of recreation periods, as well as the gradual increase of fatigue.

The Ebbinghaus 'method of combinations' was used by its author in 1897,[1] in extensive tests on school children of five grades, before the first hour and after each of the next five. Passages with words skipped were given to the pupils to fill in and the results were scored in number of spaces filled and number of errors made. He found, with few exceptions in any grade, a gradual increase of errors till noon, a recovery, then another drop in ability. The youngest ones fatigue most rapidly, as shown by the number of mistakes. This seems to be the typical curve for children under work conditions.

Mathematics, considered hardest of primary studies, has naturally been much employed as a fatigue test. Addition or multiplication was used for more or less extensive diurnal tests by Oehrn ('89), Burgerstein ('91), Laser ('94), Schulze ('95), Amberg ('96), Friedrich ('96), Kemsies ('96), Ebbinghaus ('97), Rivers and Kraepelin ('97), Roemer ('99), Thorndike ('00), Kraepelin ('03), Ellis and Shipe ('03) and others. The results as a whole tend to show a de-

[1] 'Une Nouvelle Méthode d'Appreciation des Capacité Intellectuelle,' *Rev. Scient.*, 4 e S, 8: 424–430. 1897.

crease of ability in children at the periods just mentioned. Thorndike's results[1] present a striking contrast to those of the majority, as to both adult and child students, and for that reason will be given more attention. His chief object was to test ability to do mental work before and after periods of hard mental exercise. His study comprises four separate articles.

His first article deals with mental fatigue in adults. First, mental multiplication of numbers of several places was used as a test on three subjects for four days, two trials in the morning, and two at night after from seven to twelve hours' work. The results referred to the night period were: for subject I., greater speed, less accuracy; for subject II., greater speed, greater accuracy; for subject III., greater speed, less accuracy. "In all cases feelings of fatigue were reported at the start of the later experiments."

Next, addition was used—twenty numbers of five figures each—with two subjects. They both did better before the day's work. These results are based on about ten before-work and ten after-work trials, but nineteen different days are employed. This looks like another case of the kind already frequently mentioned, in which every period concerned is not represented in each day's records used in the results.

Then he investigates the influence of mental work of a particular sort on ability to do the same sort of work. On the whole, there was improvement in rate and accuracy at the second period. He concludes that incompetency does not come in proportion to the work done. "The decrease in energy does not have enough influence to outweigh the influence of practise. There is no pure feeling of general mental incompetency." The feelings of fatigue, as far as present, were not measures of ability. Confusion exists in experimental investigations between lack of desire and ability to do work.

His second article treats of mental fatigue in school children. First, multiplication was employed with 750 Scranton and Cleveland school children, 375 being tested before the morning session and 375 at the end of the afternoon session. It was found that the later students did 99.3 per cent. as much work as the earlier; made 103.9 per cent. as many mistakes; and had 114 per cent. as many bad papers. Other tests in spelling and memory showed little or no diminution in ability in the afternoon. It is seen that there is here some agreement with the results of Rice's examinations of children. Of the child's ability to do mental work after a half or whole school day, Thorndike says, however, that 'he is just exactly as able,' and that boredom is accountable for 95 per cent. of the apparent fatigue in

[1] 'Mental Fatigue,' *Psych. Rev.*, 7: 466–482, 547–579. 1900.

schools during the day, while good teaching is the cure. His pedagogical inferences should be read in their entirety to get the full force of his contention. His conclusions seem to the present writer to be in the right direction but rather too extreme.

The third article deals with fatigue of special functions in adults —marking out words that contained the letters *e* and *t*; estimating small areas for several hours; memorizing series of numbers; correcting examination papers; assorting catalogue cards. He finds little fatigue evidenced by the single results, but they give one a somewhat different impression when considered *as a whole.* One thing is obvious, namely, the quantity of the work is much more likely to be sustained than the quality. This appeared also in the first set of experiments and is quite in harmony with the outcome of my own experimentation. It is possible that irregularity and inaccuracy of functioning are better, because more refined, indications of fatigue than diminished quantity, though actually the two groups of phenomena are not to be separated.

He takes up the question, in the fourth paper, as to whether physical fatigue is a legitimate measure of mental fatigue, and concludes that it is not. Other data in this direction were adduced above.

The ground covered by Thorndike's work was extensive, though the series of tests were often short; there will perhaps be general agreement with his conclusion that, judging from the evidence adduced, the amount of late-day inefficiency, due to fatigue, is less than is usually assumed and than one might expect by consulting one's feeling only.

Memory and association in various forms have been favorite methods for determining mental fatigue; figures, nonsense syllables, words, objects, forms, colors, etc., have been used as materials for the tests. It is undesirable to attempt expression of the results of all these investigations, and the same may be said of the outcome of a variety of minor forms of fatigue tests. There are few authors worthy of note who do not accept the idea that 'fatigue' is present in school children before the end of both day sessions, and that recesses, diversions, etc., produce marked improvement of ability.

Schuytens[1] is one of these few. With a class of boys and one of girls, about eleven years old, he found a great inferiority of afternoon work in memory when the first test was given in the morning, but just the opposite when the first was given in the afternoon and the second the following morning. His figures give percentages of

[1] 'Sur les Méthodes de Mensuration de la Fatigue chez les Ecoliers,' *Archives de Psych.*, 2: 321. 1903.

efficiency as follows: (1) girls, 62.6 A.M., 55.1 P.M.; boys, 57.9 A.M., 35.0 P.M. (2) girls, 77.5 P.M., 69.6 A.M.; boys, 64.0 P.M., 58.1 A.M. He concludes that the first experiment on children is always the best and must be eliminated before results are comparable, and that this is due to fluctuations of interest and not to afternoon fatigue. The pedagogical suggestion here is quite similar to that of Thorndike above.

Opinion still remains rather diverse as to the best hours of school opening and closing; the exact number, position and length of recitation and recess periods; whether diversity of occupation, gymnastics, etc., furnish real relief and to what extent; amount of home study desirable, and other matters of less importance. These questions will scarcely be solved by investigating fatigue alone, the causal factors being more diverse and complex than that term technically covers. A proper line of effort for the practical educator is not to study fatigue less, but to make fewer assumptions as to its presence and amount, and to study just as conscientiously the other causes of temporary mental inability.

After thus covering the accomplished work of this field, it remains to decide how much the diurnal course of efficiency is regularly affected by this very important factor.

Joteyko[1] considers fatigue a means of defence of the organism, operating in three ways: (1) it produces paralysis of the nerve terminations as an *immediate*, physiological defence; (2) the traces left by the unpleasant sensations tend to ward off similar returns—are a *preventive*, psychological defence; (3) while as a *consecutive* defence it renders the organism more resistant to fatigue. The last suggests Binet's assertion[2] that "even a book could be written entitled 'Necessity of Fatigue for Physical and Mental Hygiene'." In any event, fatigue lowers the expenditure of energy by introducing more inefficient performance. This is true of physiological, sensory and mental functioning. Its approach should, therefore, herald a diminished motor force, speed and control; a lessened sensory discrimination; and a reduced mental speed, regularity and accuracy. This being granted, the first and perhaps most obvious thing about fatigue in relation to our problem is that it does not affect all our functions simultaneously or evenly, yet it is sometimes discussed as if it did. This may partly be ascribed to its confusion with feelings of fatigue, which seem to us subjectively to cause a

[1] 'La Fatigue comme Moyen de Défense de l'Organisme,' *C.R., IV. Cong. Int. de Psych.*, Paris, 230–231. 1901.

[2] Binet et Henri, *op. cit.*, p. 302.

general and pronounced decline of all our capabilities. But the distinction between them is imperative because the difference is real.

IV. Inertness and Nervousness

The distinction between fatigue and inertness, referred to above, needs here to be recalled and emphasized. It may be thought that the introduction of this term in a technical sense is a needless subdivision of terminology. But inertness is as distinct from fatigue proper as weariness is; neither is it the same as the latter, as some German writers have assumed. It differs from fatigue in that there is not present, nor could there conceivably be under the given conditions, any cell decomposition, clogging, poisoning or other histological characteristic of the purely fatigued cell. It differs from feelings of fatigue in that it has a different physiological basis and can not be so thoroughly eliminated by introduction of interesting or 'reinforcing' stimulations of any sort. It *may* be, and apparently often is, accompanied by feelings similar to those of fatigue, though less unpleasant. As already intimated, the condition as a whole may be likened (not histologically) to that of a well-advanced convalescent who suffers no pain or disagreeable affections, but is simply weak and may be *feeling* well. Cowles[1] calls cases of early morning, relative inefficiency 'pathological fatigue,' but their occurrence is much too common and apparently normal for that to be wholly acceptable. Wagner[2] also calls them the same, in reference to skin-insensitivity, but the writer is inclined to the other view, save as to particular cases. Inertness is a condition of not being wholly waked up and warmed up, and is normal after sleep or inactivity.[3]

Inertness may be considered a condition of under-stimulation; obversely, nervousness is a condition of over-stimulation—a sort of excessive 'warming-up'. However caused—whether by mere excitation, by feelings of fatigue, by disease or otherwise—there can be no doubt that nervousness acts concomitantly with fatigue in setting the limit to efficiency in certain kinds of mental work. Other kinds, as referred to in discussing the authors, seem benefited by a mild amount of it. The same things may be said about other human employments, some being favored by nervousness—especially those

[1] *Neurasthenia and its Mental Symptoms,* Boston, 1–104. 1891.

[2] *Unterricht u. Ermüdung,* Berlin, 1–134. 1898.

[3] The repugnance experienced by so many people, to reassumption of their week-day toils, on Monday, after a day of rest (?) is due, in part at least, to some such a deadening by inactivity. 'Blue Monday' instances getting into harness again after a 'let-down.' The true psychology of stretching and of gaping would also shed light here.

requiring speed, as exemplified by the factory employees—and some impaired, as noted in the discussion of various accuracy tests.

The extent to which the inefficiency of the later part of the day is due to weariness and how far to real fatigue and nervousness is a hard question to solve. Objective tests, whether of the 'spurt' or prolonged type, probably give a better idea of the real capacity at any period than do our subjective feelings, while the latter seem more indicative of what we are likely to do under ordinary conditions. Effort was made to get some data on this matter by having different people draw daily curves of their efficiency as estimated by their feelings, but only a few records were secured. In Fig. 4 are shown such curves for five of the subjects used in the author's experiments.

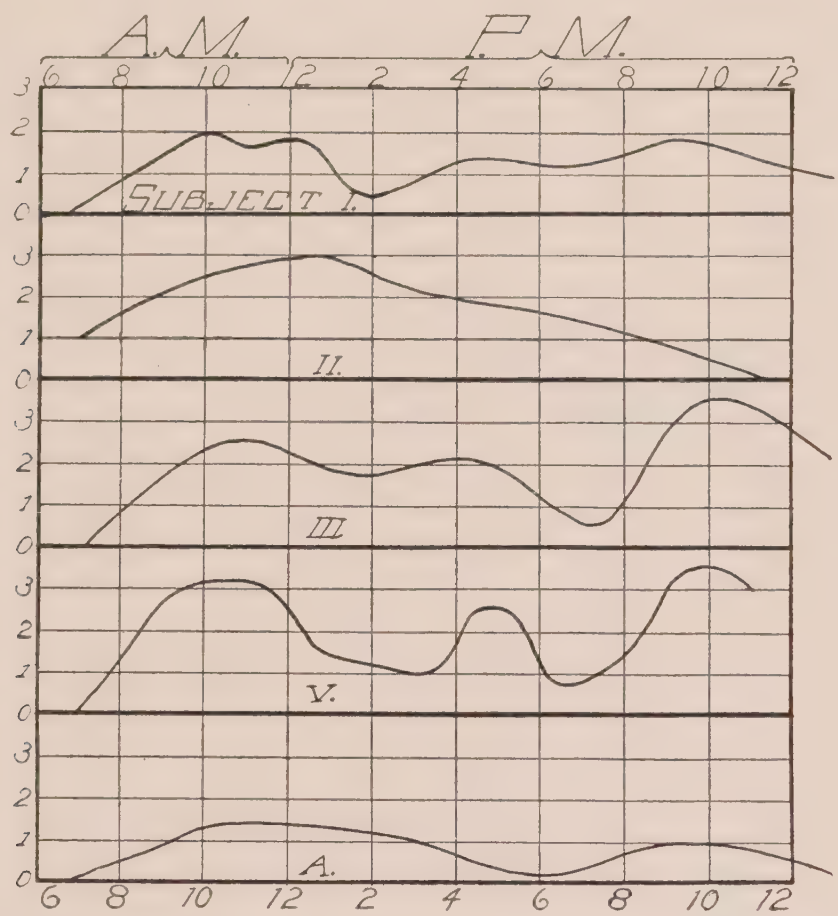


FIG. 6. Diurnal Curves of the Subjective Feeling of Efficiency.

These curves would be more interesting for comparison with the actual records of the subjects if the operation of comparison were less intricate. The purport of the paper thus far has been against indiscriminate lumping of physical or mental functions in order to get some sort of curve of 'general ability'. The tests and test periods were too few, in most cases, to make it possible for separate curves to be reliably drawn for rate, accuracy, strength, etc., and this was not attempted, save in the rough way indicated by the following

general statements. Subject II. seems actually to follow his curve the closest, and III. the least closely, relatively, to the greatest number of tests. On the whole about 60 per cent. of the actual curves might be said to resemble the affective ones rather closely. Strength seems most inversely, and addition most directly, correlated with the feelings, though the number of common tests is too small to make this very reliable.

The afternoon drop in all these curves and the high night feeling of ability, shown in all but one, appear to be rather characteristic of students. Five professors and a number of students have told the author that this is a true expression of their feelings. Much betterment occurs where there is need of 'buckling down' to some particular task in the afternoon, but to what degree this takes place or is possible is a question.

This matter of the relations between what one can do, is likely to do and does do is one upon which a large quantity of curves, like those presented above, would probably shed some light. In addition to the 'general tendencies' in these curves, to which attention has been called, it is seen that all of the five estimate themselves at a low figure for the first period. This is strictly in accord with the fact disclosed by their actual tests. Here feelings of fatigue apparently are present. However, the morning feeling, after introspective analysis, is connected by four of them—the other being uncertain—rather directly with some physical basis, while that of the afternoon is referred to one more distinctively mental. Though the distinctions here are vague, these few cases suggest that there are 'feelings of inertness' just as there are 'feelings of fatigue'. Theoretical psychological principles also lead to this supposition, if it is true that inertness as described is a fact. From the evidence in hand the relative importance of these various factors can not be satisfactorily judged.

V. Sex and Age.

It has been pointed out frequently in the preceding pages that there seems to be in adults a tendency for females to reach an earlier maximum of ability than males, and children than females. The greater influence of fatigue and weariness with both women and children is apparent, and the recovery after meals and reactions seems also greater.[1]

[1] Of 200 persons replying to a questionnaire sent out by Partridge ('Second Breath,' *Ped. Sem.*, **4.** 1896–1897), 66 reported experiences of physical 'second breath'—recuperation with slight or no rest, after exercise—of whom 30 were females and 36 males; 102 reported mental 'second breath,' of whom 89 were females and 13 males.

This running down in children, as far as it is a fact, is not due to uninteresting teachers wholly, nor yet to hard work, but is rather independent of occupation, if the following is a correct interpretation of results obtained by Rivers and Kraepelin[1] from experiments on the effect of intervals of rest upon work ability. Beginning at 8 A.M., the subject was required to spend four half-hour periods in adding, each such period being followed by a half-hour period of rest. Of the three days' results that were used, all show increase of ability after the first pause, but only one day shows this after the second pause, and none after the third. The inference was that the first rest was enough to effect complete recovery from the fatigue of the preceding addition; the second was only partially enough; and the third was quite inadequate. But, if there was *entire recuperation* after the first half hour's work, unless a *naturally* deteriorating disposition intervened, the second and third rests should have been quite as effective as the first. The same thing comes out even more positively in a second series of experiments, similar in every way to the former save that an hour's rest followed a half hour's work. In this case the greatest efficiency was again manifested after the first rest and thence there was a steady decline, though the first half hour's point of deficiency was not again reached. This was taken to mean that the practise effect and momentum were lost in the large rest intervals, while the fatigue effect was too great to be overcome after the second addition, just as in the other series. It is, however, very improbable that the fatigue effect would last over an interval long enough to destroy the practise effect. What probably took place was a normal decline that was merely hastened by the special fatigue of the tasks imposed and by a growing lack of interest. Children lose in efficiency much more readily than adults, but also recuperate more rapidly. The reason lies in the facts that they enter into what natively interests them with more fatiguing zeal than adults, while, on the other hand, they are more prone than adults to surrender to their feelings of fatigue where their interest is not so intimately engaged. To a lesser extent the same is true of women.

VI. Brief Summary.

It has been urged that the night-day rhythm imposes on us corresponding periods of sleep and activity whose recurrence is the basic condition of diurnal periodicity in efficiency. The sleep effect is prolonged beyond waking as a sort of inertness which is neither real fatigue nor merely feelings of fatigue, but is usually accom-

[1] 'Ermüdung u. Erholung,' *Psych. Arbeiten,* **2**: 627–678. 1896.

panied by feelings of inertness or of fatigue, or both. It is pronouncedly manifest in muscular abilities, especially strength, but seems less and less apparent and persistent as the mental field is entered. The process of growing awake is accelerated by a progressive increase of sensorial responsiveness which successive stimuli, acting cumulatively, seem to entail on the organism, and this continues till a normal limit is reached or some modifying factor interferes. Chief among such factors are personal habits, meals, fatigue and feelings of fatigue, nervousness, sex and age. The effects of habits (physical, social, mental, etc.) and of meals vary according to the particular case, but generally speaking they institute a recurrence of like conditions, effective even during the temporary discontinuance of the habits. Real fatigue sets the limit to the absolute maximum of efficiency, but it is probable that feelings of fatigue have more to do with the curve of our ordinary, practical efficiency —of what we actually accomplish. It appears that women expend themselves proportionately more energetically than men in things in which they are intimately interested, and at the same time that their feelings of fatigue are stronger and exercise a more deterrent influence where their personal interests are not so immediately concerned. This seems increasingly true of children, and hence we find in these two groups a corresponding inclination to an earlier maximum of efficiency, but complicated by a more facile recuperation.

E. CONCLUSION

The attitude of the author in this paper has been conservatively favorable to the idea of a few, broad diurnal variations of a rather general nature, coexisting with more numerous and intensive variations in individuals. Such, in fact, seems to be the outcome of the investigation and of the collation of data from other sources. Scientifically, the application of such a conclusion is both direct and valuable. For its truth carries with it the suggestion that psychological and physiological investigators would be obliged to take into consideration more conscientiously than heretofore the fact of periodicity in individuals. Comparative experiments should not be performed indifferently at varying times of different days, if exact results are to be expected. Not only are some variations of ability, between certain periods, as great or greater than sex differences in a homogeneous group, but some of the latter may possibly be accounted for by reference to the differences between the diurnal cycles of the two sexes.

When it comes to making a more practical application of the fact of periodic variation, we become principally interested in the *quantitative value of the differences.* If only a slight difference occurs between the extremes of diurnal efficiencies, we should doubtless take no account of it in any voluntary ordering of our lives. Even in the event of a larger difference, our peculiar subjective organization makes it a question worth asking by each person whether the reduction of the inefficiency at any period should be attempted, since such incompetency at one period *may* often insure, in his individual case, better subsequent work than otherwise would have been performed. Many writers are on record as being unable to compose at certain times, perhaps for days, weeks or even months. The explanation of these periods of enforced inactivity furnishes a good problem for investigation, but one can scarcely disbelieve that they contribute, in some way and degree, to the betterment of future functioning. There is here a practical problem for every one to solve in his own case; and at the same time a problem of general scientific interest.

A general expression of the quantitative differences between the efficiency at different times of the day could be given, if records for 15 days—10 periods each—of 100 individuals, were available in a number of the motor and mental activities. The figures of the wire-

stitchers (p. 35) offer material for illustration. The average of the maximal and minimal number of magazines handled by an operative approximates her mean speed per day. Calculation shows the subjects to be, at the minimal period, below their respective averages, by the following per cents.: 5, 6, 4, 13, 7, 6, 7, 3. This, of course, is very rough, as it takes no account of the reliabilities of the various figures; but as far as it goes, it indicates that in the employment of adults in manual labor one might expect the early morning, where the minima mostly occur, to return in production about 6 per cent. less than the day's average, and from 10 to 12 per cent. less than at the best period. Allowance must, however, be made for the fact that, if the women had worked every night, instead of alternate ones only, these results would doubtless be somewhat altered.

Would it then be better for the work-day to be shortened at the morning end rather than, as customarily, at the night end? It might, if there were any guarantee that the employees would keep to their same hours of rising; otherwise no improvement would be expected. The 'warming up' must be effected, whether it be early or not, and late sleep usually retards the process. Even if it were practicable for an employer to 'exercise' his workers vigorously for an hour before starting them on pay-time work this would scarcely prove profitable to him, because of the involved expenditure of energy needed in their actual work; and it would only be profitable in case of a shortened day and time-work. In piece-work, since pay is dependent solely upon the amount done and not upon the time consumed, there is nothing in the problem of diurnal rhythms that would interest the employer, save when the rapidity with which he might want a special job finished is in question. Even in this instance, the application would be limited to cases in which *extra* 'hands' were to be secured for the occasion—that is, they could be hired only for their periods of high efficiency; this would hold good also for part-time time-workers—because any reassignment of his 'regulars' to such special 'rush' work would be governed by the actual amount of work required to get out on time the regular jobs on hand. But it would be of interest to the employee, if the extra exercise could be endured, since it would enable him to start in at a rate which he must else more slowly attain. Beyond this, there seems no practical industrial application of any consequence.

As before stated, the practical value of investigations of this question has perhaps most particular reference to school life. Most of them have been carried on with this in view: whole curricula have been suggested, ordered in accordance with the results of different researches. It will be clear to the reader of the preceding pages

that such curricula rest on insecure bases as yet, but that the empirical work has not, therefore, been without value. The main result of the present research, in this connection, consists in restablishing a principle already well known in the pedagogical field, but not well enough recognized. Kraepelin's thought that 'the present arrangement of school programs makes it a necessity to have tedious teachers in whose classes the pupils may rest themselves by inattention' may have some truth in it, but it is much more worth noting that the most wholesome and economical development of the pupil makes it necessary to have interesting teachers in whose classes the pupils may rest themselves by a more 'frictionless,' and develop themselves by a more fully utilized, expenditure of energy. The feelings of fatigue, to which they are often exposed, are more deadening intellectually than the real fatigue of a day's interesting work and, in addition, do not represent actually *growthful* exercise of the functions concerned.

As far as older people are concerned, this principle can be applied somewhat similarly. The feelings of languor and weariness, to which one may become more subject as he indulges in them, might more and more be made to disappear, as far as they are not due to structural defects or any constant and uncontrollable cause, if a definite course of activity were consistently pursued in spite of them. In this case, a sort of artificial interest ultimately replaces the native spontaneity of the children, and institutes a condition of less expenditure of energy in performing the given act at the given time. Kraepelin is of the opinion that 'every human being has his own peculiar way of work, which usually shows itself regularly in the same manner during every working period.' That is too sweeping, but it is probable that the older one grows the more it tends to become true, because habits become more firmly ingrained.

Perhaps a few remarks should be made as to the existence of so-called 'morning workers' and 'night workers.' When the evidence of the preceding pages is reviewed, especially that concerning students and authors, their existence can scarcely be questioned. The Germans have long accepted the matter as settled and Külpe can be cited as a splendid example of the fact involved—as a night worker. Here again the quantitative aspect—how many the persons and how much the difference—are the all-important practical considerations, and here again it must be said that ample data for their determination are not as yet at hand.

The range of the results set forth in this paper has been so extensive that a definite impression as to where their main tendencies lie may still be lacking. For that reason a method was diligently

sought by which they could be presented, either tabularly or graphically, in such a way as to indicate this in small scope. However, when one attempts properly to weight data, obtained from diurnal periods varying in number from 2 to 24; from various measurements of various activities; from subjects of varying number, age and sex; and under other varying conditions—the task is found to be quite hopeless. This is not strange, however, considering that even the 'laws' of physics can not always be expressed in one figure or formula. For instance, expansion of volume by heat has several coefficients for solids; a constant one for gases; two for liquids, which only partly hold true; while water in certain phases exhibits phenomena contrary to the general law. Much more do individuals differ psychologically. After all, if all the figures in the text were reduced to some percentage basis, they would still be incomparable for this reason, that an increased efficiency of 10 per cent. in one case would probably not at all mean the same in reality as an increase of 10 per cent. in another function. Such a summary would be satisfactory in its compactness, but misleading as to fact. For the chief specific conclusions, therefore, the reader is referred to the brief summaries on pages 13, 14, 40, 69, 91, which together cover the whole investigation on its empirical side.

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